UNITED STATES DEPARTMENT OF AGRICULTURE

# BULLETIN No. 339

Contribution from Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C. PROFESSIONAL PAPER April 21, 1916

# EXPERIMENTS ON THE ECONOMICAL USE OF IRRIGATION WATER IN IDAHO.

By Don H. Bark, *Irrigation Engineer.*

CONTENTS.



## INTRODUCTION.

This bulletin contains the results of experiments made in cooperation with the State Land Board of Idaho to determine the quantities of water needed to produce the ordinary farm crops on the types of soil common to that State. The experiments, in addition to investigations strictly bearing on such irrigation requirements, included certain supplementary investigations.

The irrigation-requirement experiments extended from 1910 through 1913 and consisted in applying different quantities of water to plots receiving similar treatment except for this factor. It is considered that these experiments fix within reasonable limits the amount of water which must be delivered to fields to produce profitable crops under the conditions described. The supplementary experiments were made for the purpose of determining how much additional water must be allotted to cover waste and losses between the point of diversion and the fields to be irrigated.

The conclusions contain a discussion of the factors affecting irrigation requirements in actual practice.

Note.—The work on which this bulletin is based was done under a cooperative agreement between the Office of Experiment Stations and the State Land Board of Idaho, several of the canal companies and the railway companies operating in Idaho contributing to the expense of the work. The bulletin will be of interest to officials administering the water supply of the Western States, to students of irrigation practice, and to farmers.

## PLAN OF INVESTIGATION.

The investigation was planned to show the actual irrigation requirements of the various soils and crops common to southern Idaho. The staple crops—alfalfa, clover, pasture, spring and winter grains, potatoes, and orchards—have all been represented. The fields had a varying topography, with slopes ranging from 20 feet in 100 to 4 feet per mile.

In order to make the results practical and dependable and such as good farmers might obtain under average conditions it was decided: (1) That the investigation must be conducted in the main by men employed especially for the purpose and without outside interests; (2) that the areas experimented upon must be comparatively large; (3) that the investigation must extend over several years, so as to eliminate or neutralize the individual characteristics of the different seasons; and (4) that the mere measurement of the water applied to single tracts would be insufficient, for this would not show the yield that might have been produced by a greater or lesser application of water.

### SCOPE OF INVESTIGATION.

As mentioned above, the study extended through four seasons, during which time water was measured upon 529 individual tracts, having a total area of slightly over 3,600 acres. In order to determine the normal quantity used by the farmers when such use was unrestricted and not influenced in any way by the proximity of experiments, the water applied by them to 28 other tracts, having a total area of 1,306.8 acres, was measured with automatic water registers.

The water diverted and used by seven different canal systems in 1911 and nine systems in 1912 was measured, and the areas irrigated under them were determined.

In a comprehensive study of the transmission losses of canals the seepage losses in 118 sections of different canals with an aggregate length of 278.3 miles were determined. The canals measured varied in discharge from 0.07 to over 3,190 cubic feet per second, and in cross section from 0.117 to 984 square feet.

The percentage of nonirrigated or waste land in a typical project was also determined, 16,067.8 acres located in two bodies being surveyed for the purpose.

The territory covered extends from Rigby, with an altitude of 4,950 feet, in the upper Snake River Valley, to Weiser, with an altitude of 2,114 feet, on the western boundary of Idaho, a distance of 368 miles.

### SELECTION OF TRACTS.

As it was imperative that the final results of the investigation should show a duty that could be secured by good average farmers without more expensive preparation than would be justified, only such tracts as were considered typical in regard to soil and practical in regard to preparation were included, and they were not especially prepared for the investigation in any way.

### DIVISION OF TRACTS AND VARIATION OF WATER.

Each tract selected, wherever its topography and size permitted, was divided into three approximately equal parts, care being taken to select only such tracts as had uniform soil conditions and previous preparation and cropping throughout, in order that the results from the different plots might be strictly comparable. In most cases the tracts consisted of about 15 acres, divided into three plots of about 5 acres each, in the same crop on the same soil, with all conditions uniform, except that a different volume of water was applied to each plot.

Weirs were installed in the ditches leading to and from each tract in order to measure the water applied and wasted. These tracts were selected from average irrigators' farms in representative districts, and the owner of each was allowed to select one of the plots into which his tract had been divided and to irrigate and handle it during the season and apply the water at such times as had been his usual custom. The two remaining plots were irrigated by applying more water to one and less to the other than the owner applied to the plot he himself had selected. The yield produced usually indicated which plot had received the supply of water best suited to the soil and crop in question. Usually four or five experimental tracts were selected from as many farms in the same neighborhood, since one assistant could look after and irrigate that number of tracts provided the same were located within a radius of 2 or 3 miles. The water wasted from each tract was measured, and all amounts tabulated in this report unless otherwise specified represent only the quantities retained upon the land.

### MEASUREMENT OF WATER.

Cipolletti weirs were used in the measurements, the weir boxes usually being built of 1-inch lumber. The weir plates used were 16-gage galvanized iron. The head on the weirs was measured each hour or oftener, as was required, with small steel rules graduated to 0.01 foot. Measurements of the head were made from the tops of spikes driven vertically into substantial 2 by 4 or 4 by 4 stakes placed in the weir pools upstream from the weirs, at about twice their length.

The spikes in the tops of the stakes were leveled with the weir crests by means of long carpenter's levels, great care being exercised to keep them level at all times. It was found that excess velocity of approach, due to the filling up of the weir pools, was the most frequent source of error in weir measurements, and special care was taken throughout the entire investigation to maintain weir pools of sufficient size and depth to insure a slow velocity of approach. The formula used in computing the discharge over the weirs was $Q=3.367\ L\ H^{\frac{3}{2}}$, where $Q$ = discharge in cubic feet per second, $L$ = length of crest in feet, and $H$ = head or depth of water on the crest in feet.

Usually the head was measured every hour, but where the flow remained rather constant measurements sometimes were taken at two-hour intervals, and where much fluctuation occurred the head was measured oftener than every hour. Plate I, figures 1 and 2, should furnish a clear idea of the type of weirs used. The volume of water diverted by the large projects was determined by daily gage readings and current-meter determinations.

## DETERMINATION OF AREAS AND YIELDS.

With the exception of the large projects, all areas included in this investigation have been determined by transit and chain surveys. The transit notes were plotted on a scale of 100 feet to the inch, and the acreage was determined from the map with a polar planimeter. It is believed that the areas of all of the tracts in this variation experiment have been determined within 0.01 acre.

The crops from the three plots into which each tract has been divided have invariably been cut, stacked, and thrashed separately, and weighed wherever possible. In cases where grain or alfalfa fields were located at long distances from a set of wagon scales and weighing has been impracticable, the yields from the different plots have been determined by the automatic weighers attached to the thrashing machines and by the measurement of the hay in the stack. While the determination of the yields by the latter method has not been absolutely accurate, the same method has been used with all plots into which a tract was divided, thus insuring comparable results.

## CLASSIFICATION OF SOIL.

The soils on the different tracts have been classified with respect to their mechanical composition only, chemical analyses having been made in but few cases. Representative samples of the first, second, third, and fourth foot of soil from each tract experimented upon have been secured and prepared and are now filed away for further reference. The soils varied from the finest of adobe clays to the coarsest gravels. The extremes of soil which have been included

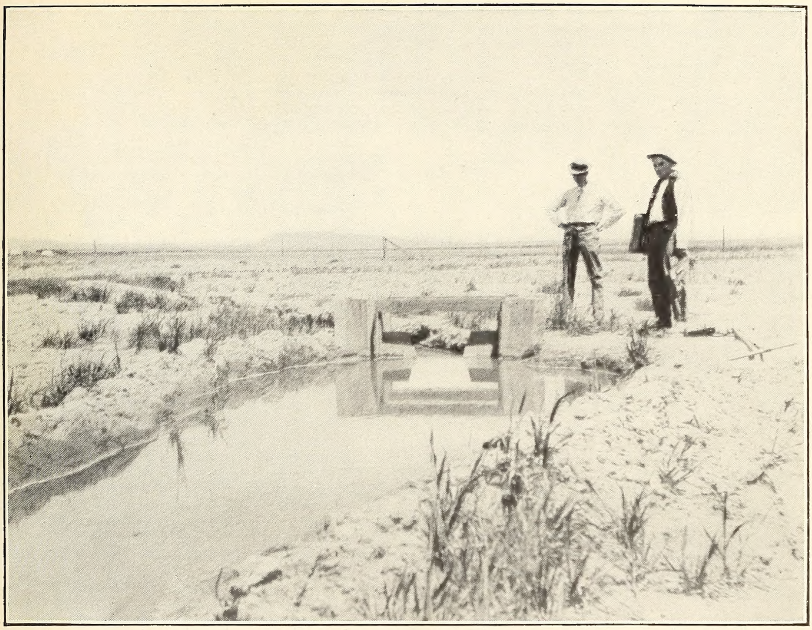


FIG. 1.—UPSTREAM VIEW OF CIPOLLETTI WEIR USED IN THE IDAHO INVESTIGATION.

FIG. 2.—DOWNSTREAM VIEW OF CIPOLLETTI WEIR USED IN IDAHO INVESTIGATION, SHOWING METHOD OF MEASURING.

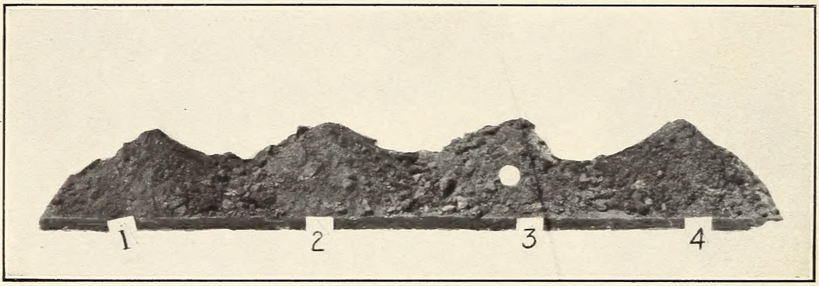



FIG. 1.—SAMPLES OF FIRST, SECOND, THIRD, AND FOURTH FOOT OF CLAY LOAM SOIL OF FINE UNIFORM TEXTURE.

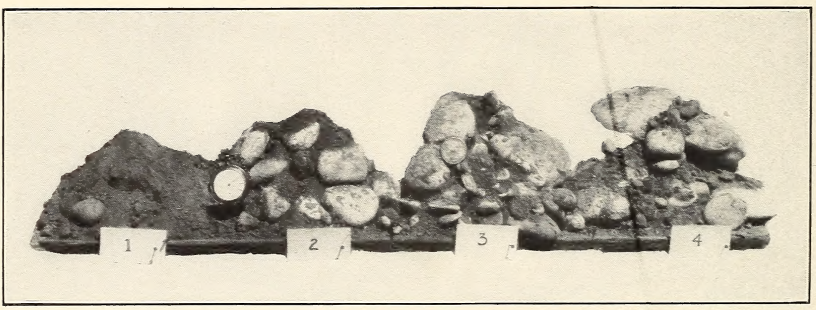



FIG. 2.—SAMPLES OF FIRST, SECOND, THIRD, AND FOURTH FOOT OF VERY GRAVELLY SOIL.

e well represented in Plate II, figures 1 and 2, which show the average soil of the first, second, third, and fourth foot of two of the experimental tracts.

### MOISTURE DETERMINATIONS.

The primary object of this investigation having been to determine the quantity of irrigation water required by the soils and crops of a farm or project, it was not considered advisable or practical on account of the large territory involved to go to the expense of making exhaustive soil-moisture determinations on all tracts throughout the season. A careful determination of the moisture in the first, second, third, and fourth foot of soil of each plot experimented upon was made, however, before the first irrigation and about the time plants started to grow in the spring. This was done by securing a large number of representative samples from each tract and drying them in an oven at a temperature of 108° C. While the available soil moisture has not been taken into consideration in averaging the quantities of water used and the yields obtained, these determinations have permitted of a careful comparison of the results secured from the different experiments.

### REIMBURSEMENT OF LOSSES.

The owners of the various experimental tracts included in the investigation have been reimbursed for all crop losses that have been experienced because of variation of the water supply. The yield of the plot selected and handled by the owner himself was used in each case as a basis for determining the loss. Reimbursement was found necessary in connection with less than one-third of the tracts included in the investigation.

### METHOD OF INTERPRETING RESULTS.

The correct and proper analysis of the results has been the most difficult part of the entire investigation. Even when the greatest care is used in agricultural experiments there are many factors other than those under observation which may influence the yields. Normally it has been assumed that the plot which produced the best yield in each experiment received the best application of water. In many cases, however, the largest yield has exceeded the yield of one of the other plots by not more than 2 to 5 per cent, when the quantity of water applied for the maximum yield exceeded that applied to the next largest yield by as much as 100 per cent. In such cases it is apparent that if economy of time and water is to be considered, it is better practice to apply the smaller quantity of water. The investigation as a whole has emphasized the fact that the results from single experiments can not be depended upon,

because there have sometimes been great variations in the yields produced by the same quantity of water on the same crop upon adjoining farms. These variations have made it very evident that dependable results can be secured from agricultural experiments only by basing conclusions upon the average of results from a large number of experiments.

## WEATHER CONDITIONS IN IDAHO DURING THE INVESTIGATION.

It has not been considered practicable, although it would have been desirable, to install a rain gage in connection with each tract

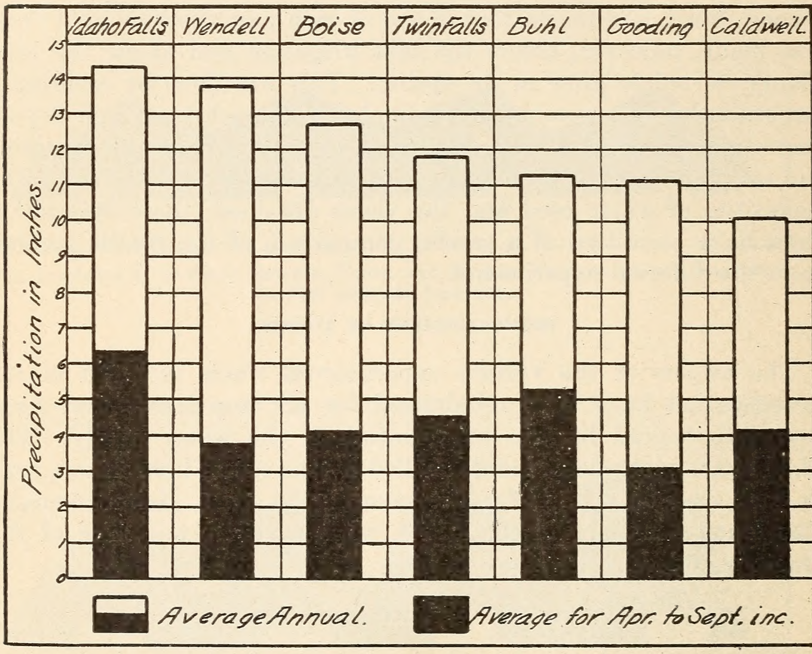



FIG. 1.—Comparison of average annual precipitation with that occurring during the growing season.

experimented upon. The United States Weather Bureau has a large number of cooperative observers' stations scattered quite uniformly throughout the territory involved in the investigation, and the precipitation recorded at the station nearest each tract has been used. This may be slightly inaccurate, but the errors are compensating and small at the most.

The normal annual precipitation in the districts of southern Idaho which have been investigated ranges from slightly less than 10 inches per annum at Oakley to 17.75 inches at Hailey. Hailey is situated at a comparatively high altitude, and the precipitation in this place is consequently above the average for irrigated southern Idaho. The average precipitation in the typical irrigated districts

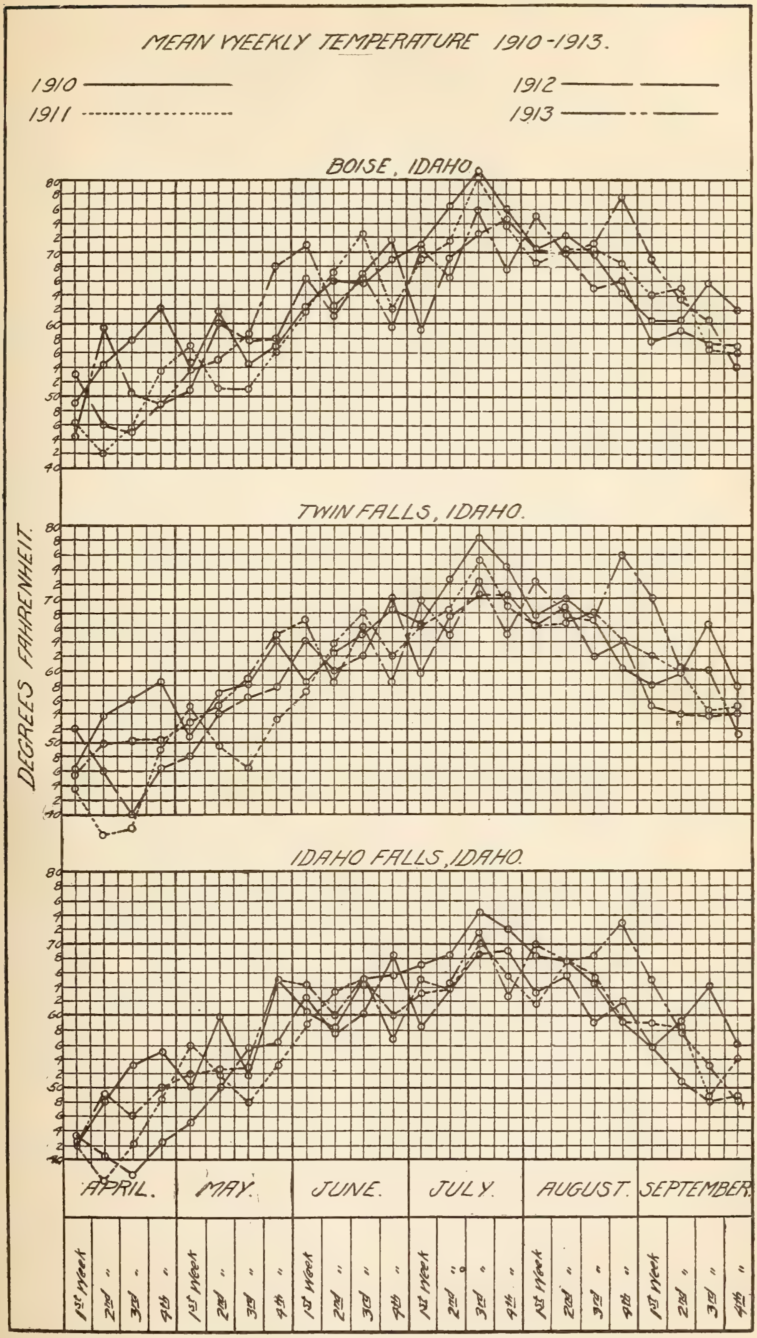



FIG. 2.—Range of temperature during the growing season for three representative districts.

ranges from about 10 to 14 inches per annum, of which from as low as 3 inches to as high as 6.7 inches, or about one-third, occur during the growing season from April to September, inclusive.

The growing season of 1910 in Idaho was the driest on record. The precipitation during seven consecutive months, from March to September, inclusive, was below normal, but the temperature ranged above normal during the entire season. The seasons of 1911 and 1912 averaged much cooler than that of 1910, but the precipitation during both of these years ranged above normal during the entire growing season, as may be seen from the tables which follow. The season of 1913 was another with high precipitation, while the temperature was a fair average of the other three years, 1910 to 1912, inclusive. The following tables and charts have been compiled from the records of the United States Weather Bureau for the purpose of showing in condensed form the weather conditions that existed during the four years covered by the investigation. Figure 1 shows the precipitation for one town in each district and figure 2 the range of temperature during the growing season for three representative districts, and it is believed that a careful study of these charts will furnish a correct idea of Idaho's normal weather conditions and of the weather experienced during the four years' investigations.

TABLE I.—*Precipitation, seasons of 1910, 1911, 1912, and 1913.*

SEASON OF 1910.

| Locality. | Length of record in years. | Average precipitation. | | Precipitation by months. | | | | | | Total for 6 months. | Per cent of normal. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | An-nual. | Apr. to Sept. | Apr. | May. | June. | July. | Aug. | Sept. | | |
| | | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | |
| Blackfoot | 14 | 10.46 | 4.84 | 0.67 | 0.78 | 0.10 | 0.21 | T. | 0.47 | 2.23 | 46 |
| Boise | 25 | 12.71 | 4.10 | 1.10 | 1.14 | .30 | T. | 0 | .50 | 3.04 | 74 |
| Buhl | 3 | 12.22 | 5.13 | .82 | .55 | .25 | .28 | 0 | ...... | ...... | ...... |
| Caldwell | 5 | 10.54 | 3.51 | 1.05 | .84 | .03 | T. | 0 | .89 | 2.81 | 80 |
| Gooding | 1 | ...... | ...... | .77 | .32 | .08 | .24 | 0 | .44 | 1.85 | ...... |
| Hailey | 8 | 17.15 | 4.04 | .81 | .80 | .06 | .27 | 0 | 1.33 | 3.27 | 81 |
| Idaho Falls | 15 | 14.45 | 6.24 | .06 | .75 | .14 | .11 | T. | 1.30 | 2.36 | 38 |
| Shoshone | 3 | 15.06 | 2.91 | .33 | .43 | .01 | .18 | 0 | .54 | 1.49 | 51 |
| Twin Falls | 5 | 12.90 | 4.40 | .73 | .52 | .06 | .12 | T. | .95 | 2.38 | 54 |

SEASON OF 1911.

| Locality. | Length of record in years. | An-nual. | Apr. to Sept. | Apr. | May. | June. | July. | Aug. | Sept. | Total for 6 months. | Per cent of normal. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Boise | 26 | 12.71 | 4.10 | 1.59 | 2.57 | 2.55 | 0.05 | T. | 0.04 | 6.80 | 166 |
| Buhl | 4 | 11.15 | 5.17 | .86 | 1.97 | 2.34 | .18 | T. | T. | 5.35 | 103 |
| Caldwell | 6 | 10.31 | 3.59 | 1.03 | 1.13 | 1.44 | .23 | T. | .12 | 3.95 | 110 |
| Gooding | 2 | 9.40 | 3.20 | 1.15 | 1.77 | 1.06 | 0 | 0 | T. | 3.98 | 124 |
| Hailey | 9 | 16.27 | 4.30 | 1.67 | 2.91 | 1.53 | 0.04 | T. | .03 | 6.18 | 144 |
| Idaho Falls | 16 | 14.00 | 6.00 | .95 | 2.29 | 2.67 | .30 | 0.07 | .67 | 6.95 | 116 |
| Oakley | 18 | 9.58 | 4.61 | .15 | 1.75 | 2.76 | .84 | 0 | .30 | 5.80 | 126 |
| Twin Falls | 6 | 12.10 | 4.19 | .43 | 1.74 | .83 | .05 | 0.04 | .10 | 3.19 | 76 |
| Wendell | 3 | 13.86 | 3.96 | 1.35 | 2.00 | 1.95 | T. | 0 | T. | 5.30 | 134 |

TABLE I.—*Precipitation, seasons of 1910, 1911, 1912, and 1913*—Continued.

SEASON OF 1912.

| Locality. | Length of record in years. | Average precipitation. An-nual. | Average precipitation. Apr. to Sept. | Apr. | May. | June. | July. | Aug. | Sept. | Total for 6 months. | Per cent of nor-mal. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | *Inches.* | |
| Boise | 27 | 12.71 | 4.10 | 3.34 | 1.94 | 0.86 | 1.27 | 0.07 | 0.77 | 8.25 | 201 |
| Buhl | 5 | 10.90 | 4.99 | 1.92 | .43 | .90 | .18 | .08 | .30 | 3.81 | 76 |
| Caldwell | 7 | 10.05 | 4.13 | 1.96 | 2.05 | 1.77 | 1.22 | .21 | .50 | 7.71 | 187 |
| Gooding | 3 | 10.82 | 3.24 | .96 | 1.33 | .67 | .33 | T. | .18 | 3.47 | 107 |
| Idaho Falls | 17 | 14.23 | 6.19 | 1.94 | 1.36 | .89 | 1.60 | 2.28 | .44 | 8.51 | 137 |
| Twin Falls | 7 | 11.98 | 4.13 | 1.68 | .63 | .46 | .48 | .16 | .30 | 3.71 | 90 |
| Wendell | 4 | 13.76 | 3.82 | 1.38 | .57 | .86 | .04 | T. | .31 | 3.16 | 83 |

SEASON OF 1913.

| Locality. | Length of record in years. | Average precipitation. An-nual. | Average precipitation. Apr. to Sept. | Apr. | May. | June. | July. | Aug. | Sept. | Total for 6 months. | Per cent of nor-mal. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Boise | 28 | 12.71 | 4.10 | 0.95 | 0.58 | 1.64 | 2.01 | 0.03 | 0.65 | 5.86 | 143 |
| Buhl | 6 | 11.25 | 5.25 | .62 | 1.58 | 2.49 | 2.29 | .13 | .05 | 7.16 | 136 |
| Gooding | 4 | 11.14 | 3.04 | .47 | .15 | .91 | .73 | .08 | .05 | 2.39 | 79 |
| Hollister | 2 | 12.97 | 6.74 | .89 | 1.79 | 2.40 | 1.65 | .13 | .49 | 7.35 | 109 |
| Idaho Falls | 18 | 14.35 | 6.19 | .35 | 2.39 | 2.99 | 1.86 | .08 | .88 | 8.55 | 138 |
| Oakley | 19 | 9.99 | 4.89 | .15 | 1.36 | 3.01 | 1.85 | .84 | .65 | 7.86 | 156 |
| Rogerson | ...... | ...... | ...... | ...... | 1.25 | 4.32 | 1.29 | 1.17 | ...... | ...... | ...... |
| Twin Falls | 8 | 11.78 | 4.54 | .53 | .75 | 2.54 | 1.50 | .17 | 2.09 | 7.58 | 167 |

## RESULTS OBTAINED DURING 1910, 1911, 1912, AND 1913.

Tables II to VIII show in condensed form the principal results secured from the most of the experiments. It was evident that soils and crops differed so widely in their irrigation requirements that comparisons could be made only by grouping the data according to soils and crops. The crops are therefore segregated in two groups in the tables, according to their water requirements: (1) Spring and winter grains, potatoes, and orchard; (2) alfalfa, clover, and pasture. For convenience, the results from the three or more plots on each farm are grouped together so that the experiments on the different farms are separated slightly in the tables. The total depth applied includes only the irrigation water that was retained upon the tract in question, the rainfall during the growing season being given in another column.

TABLE II.—*Effects of different volumes of water on grains and potatoes in Idaho during the season of 1910.*

| No. of plot. | Kind of crop. | Altitude. | Class of soil. | Area. | Precipitation April–September, inclusive. | Date of first irrigation. | Length of irrigation season. | Number of irrigations. | Total depth irrigation water applied. | Yield per acre. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Feet.* | | *Acres.* | *In.* | | *Days.* | | *Feet.* | *Bushels.* |
| 1 | Oats.... | 3,968 | Slightly sandy loam........ | 3.91 | 1.49 | May 31 | 63 | 3 | 2.12 | 22.8 |
| 2 | ...do.... | 3,968 | .....do.................. | 3.73 | 1.49 | ...do..... | 75 | 4 | 2.20 | 27.7 |
| 3 | ...do.... | 3,968 | .....do.................. | 4.51 | 1.49 | ...do..... | 87 | 5 | 3.31 | 27.6 |
| 4 | Wheat.. | 3,800 | Medium clay loam.......... | 4.95 | ...... | June 5 | ...... | 1 | .87 | 44.5 |
| 5 | ...do.... | 3,800 | .....do.................. | 5.06 | ...... | May 26 | 27 | 2 | 1.44 | 67.2 |
| 6 | ...do.... | 3,800 | .....do.................. | 5.06 | ...... | May 24 | 28 | 3 | 2.20 | 59.3 |
| 7 | Wheat.. | 4,949 | Very gravelly............... | 4.96 | 2.36 | June 9 | 77 | 4 | 2.40 | 10.0 |
| 8 | ...do.... | 4,949 | .....do.................. | 4.94 | 2.36 | ...do.... | 78 | 4 | 2.26 | 11.1 |
| 9 | ...do.... | 4,949 | .....do.................. | 4.79 | 2.36 | June 10 | 77 | 4 | 2.26 | 11.3 |
| 10 | Oats.... | 4,949 | Very gravelly............... | 2.93 | 2.36 | June 3 | 54 | 4 | 3.26 | 22.0 |
| 11 | Wheat.. | 4,949 | Very gravelly............... | 4.02 | 2.36 | June 5 | 54 | 3 | 3.70 | 24.3 |
| 12 | ...do.... | 4,949 | .....do.................. | 4.98 | 2.36 | ...do.... | 54 | 4 | 4.73 | 32.7 |
| 13 | ...do.... | 4,949 | .....do.................. | 4.93 | 2.36 | June 4 | 53 | 5 | 7.08 | 30.2 |
| 14 | Wheat.. | 4,949 | Gravelly clay............... | 3.60 | 2.36 | June 10 | 31 | 3 | 2.64 | 30.6 |
| 15 | ...do.... | 4,949 | .....do.................. | 3.16 | 2.36 | ...do.... | 50 | 4 | 3.10 | 35.8 |
| 16 | ...do.... | 4,949 | .....do.................. | 3.07 | 2.36 | June 9 | 50 | 5 | 3.96 | 39.0 |
| 17 | Oats.... | 4,742 | Very gravelly............... | 2.44 | 2.36 | June 3 | 71 | 4 | 4.48 | 21.7 |
| 18 | ...do.... | 4,742 | .....do.................. | 3.78 | 2.36 | June 4 | 62 | 4 | 4.14 | 34.2 |
| 19 | ...do.... | 4,742 | .....do.................. | 4.50 | 2.36 | June 2 | 79 | 6 | 5.68 | 33.2 |
| 20 | Oats.... | 4,742 | Impervious clay loam...... | 3.46 | 2.36 | June 23 | 51 | 3 | .99 | 44.5 |
| 21 | ...do.... | 4,742 | .....do.................. | 3.44 | 2.36 | June 24 | 52 | 3 | 1.22 | 49.7 |
| 22 | ...do.... | 4,742 | .....do.................. | 3.66 | 2.36 | June 22 | 51 | 3 | 1.71 | 54.3 |
| 23 | Wheat.. | 4,497 | Very sandy................. | 4.11 | 2.23 | July 2 | ...... | 1 | .76 | 27.8 |
| 24 | ...do.... | 4,497 | .....do.................. | 2.72 | 2.23 | June 25 | ...... | 1 | 1.05 | 26.9 |
| 25 | ...do.... | 4,497 | .....do.................. | 4.76 | 2.23 | June 9 | 15 | 2 | 2.93 | 27.3 |
| 26 | Oats.... | 2,482 | Impervious clay loam...... | 4.36 | 2.81 | May 24 | 13 | 3 | 1.02 | 21.8 |
| 27 | ...do.... | 2,482 | .....do.................. | 3.56 | 2.81 | May 23 | 14 | 3 | 1.22 | 33.8 |
| 28 | ...do.... | 2,482 | .....do.................. | 5.09 | 2.81 | May 26 | 13 | 3 | 1.45 | 29.4 |
| 29 | Wheat.. | 2,607 | Uniform clay loam.......... | 4.24 | 2.90 | May 27 | 26 | 2 | .72 | 36.3 |
| 30 | ...do.... | 2,607 | .....do.................. | 3.84 | 2.90 | May 23 | 30 | 2 | .84 | 38.0 |
| 31 | ...do.... | 2,607 | .....do.................. | 3.98 | 2.90 | May 27 | 30 | 2 | 1.13 | 34.4 |
| 32 | Oats.... | 2,460 | Coarse sandy loam.......... | 3.61 | 3.04 | May 21 | 47 | 3 | 1.00 | 58.0 |
| 33 | ...do.... | 2,460 | .....do.................. | 2.77 | 3.04 | May 20 | 56 | 5 | 1.36 | 55.0 |
| 34 | ...do.... | 2,460 | .....do.................. | 2.57 | 3.04 | May 19 | 61 | 5 | 2.31 | 47.0 |
| 35 | Wheat.. | 3,800 | Uniform clay loam.......... | 4.72 | 1.85 | May 26 | 35 | 2 | .55 | 8.3 |
| 36 | ...do.... | 3,800 | .....do.................. | 4.55 | 1.85 | ...do.... | 35 | 2 | .89 | 15.9 |
| 37 | ...do.... | 3,800 | .....do.................. | 4.43 | 1.85 | ...do.... | 35 | 2 | .95 | 12.4 |
| 38 | Oats.... | 2,482 | Impervious clay loam...... | 5.16 | 2.81 | June 15 | 41 | 4 | .65 | 16.1 |
| 39 | ...do.... | 2,482 | .....do.................. | 4.03 | 2.81 | June 14 | 59 | 5 | 1.03 | 25.4 |
| 40 | ...do.... | 2,482 | .....do.................. | 4.31 | 2.81 | June 18 | 57 | 6 | 1.22 | 27.3 |
| | | | | | | | | | | *Pounds.* |
| 41 | Wheat.. | 3,572 | Medium clay loam.......... | .172 | 1.85 | .......... | ...... | 0 | .00 | 436.0 |
| 42 | ...do.... | 3,572 | .....do.................. | .089 | 1.85 | May 20 | 25 | 2 | .533 | 1,123.6 |
| 43 | ...do.... | 3,572 | .....do.................. | .088 | 1.85 | ...do.... | 43 | 3 | .713 | 1,397.7 |
| 44 | ...do.... | 3,572 | .....do.................. | .091 | 1.85 | ...do.... | 43 | 4 | .842 | 1,824.2 |
| 45 | ...do.... | 3,572 | .....do.................. | .084 | 1.85 | ...do.... | 54 | 5 | 1.210 | 2,000.0 |
| 46 | ...do.... | 3,572 | .....do.................. | .092 | 1.85 | ...do.... | 61 | 6 | 1.435 | 2,010.0 |
| 47 | ...do.... | 3,572 | .....do.................. | .083 | 1.85 | May 21 | 66 | 9 | 2.486 | 2,084.3 |
| 48 | Wheat.. | 3,572 | Medium clay loam.......... | .195 | 1.85 | .......... | ...... | 0 | .000 | 605.1 |
| 49 | ...do.... | 3,572 | .....do.................. | .088 | 1.85 | May 20 | 25 | 2 | .352 | 1,227.3 |
| 50 | ...do.... | 3,572 | .....do.................. | .088 | 1.85 | ...do.... | 43 | 3 | .533 | 1,238.6 |
| 51 | ...do.... | 3,572 | .....do.................. | .086 | 1.85 | ...do.... | 43 | 4 | .945 | 1,430.2 |
| 52 | ...do.... | 3,572 | .....do.................. | .089 | 1.85 | ...do.... | 54 | 5 | 1.100 | 1,932.6 |
| 53 | ...do.... | 3,572 | .....do.................. | .074 | 1.85 | ...do.... | 61 | 6 | 1.601 | 2,067.5 |
| 54 | ...do.... | 3,572 | .....do.................. | .089 | 1.85 | May 21 | 66 | 9 | 2.355 | 2,101.1 |

TABLE II.—*Effects of different volumes of water on grains and potatoes in Idaho during the season of 1910*—Continued.

| No. of plot. | Kind of crop. | Altitude. | Class of soil. | Area. | Precipitation April–September, inclusive. | Date of first irrigation. | Length of irrigation season. | Number of irrigations. | Total depth irrigation water applied. | Yield per acre. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Feet.* | | *Acres.* | *In.* | | *Days.* | | *Feet.* | *Pounds.* |
| 55 | Wheat.. | 3,572 | Medium clay loam.......... | 0.176 | 1.85 | .......... | ...... | 0 | 0.000 | 522.7 |
| 56 | ...do.... | 3,572 | .....do.................... | .088 | 1.85 | May 20 | 25 | 2 | .434 | 1,227.3 |
| 57 | ...do.... | 3,572 | .....do.................... | .089 | 1.85 | ...do.... | 43 | 3 | .594 | 1,359.7 |
| 58 | ...do.... | 3,572 | .....do.................... | .091 | 1.85 | ...do.... | 43 | 4 | .907 | 1,824.2 |
| 59 | ...do.... | 3,572 | .....do.................... | .088 | 1.85 | ...do.... | 54 | 5 | 1.091 | 2,102.3 |
| 60 | ...do.... | 3,572 | .....do.................... | .093 | 1.85 | May 21 | 60 | 7 | 1.786 | 2,258.0 |
| 61 | ...do.... | 3,572 | .....do.................... | .074 | 1.85 | ...do.... | 66 | 9 | 3.010 | 2,635.1 |
| 62 | Barley.. | 3,572 | Medium clay loam.......... | .962 | 1.85 | May 17 | 32 | 3 | 1.032 | 1,509.4 |
| 63 | ...do.... | 3,572 | .....do.................... | .963 | 1.85 | ...do.... | 58 | 4 | 1.312 | 1,797.5 |
| 64 | ...do.... | 3,572 | .....do.................... | .968 | 1.85 | May 18 | 68 | 5 | 1.879 | 2,026.9 |
| 65 | Oats.... | 3,572 | Medium clay loam.......... | .959 | 1.85 | May 24 | 23 | 2 | .560 | 1,444.2 |
| 66 | ...do.... | 3,572 | .....do.................... | .957 | 1.85 | May 25 | 41 | 3 | 1.097 | 1,849.5 |
| 67 | ...do.... | 3,572 | .....do.................... | .962 | 1.85 | May 23 | 51 | 4 | 1.450 | 2,047.8 |
| 68 | Wheat.. | 3,572 | Medium clay loam.......... | .563 | 1.85 | May 26 | 22 | 2 | .780 | 1,179.4 |
| 69 | ...do.... | 3,572 | .....do.................... | .591 | 1.85 | ...do.... | 40 | 3 | 1.269 | 1,539.8 |
| 70 | ...do.... | 3,572 | .....do.................... | .769 | 1.85 | ...do.... | 60 | 4 | 1.841 | 1,581.3 |
| 71 | Wheat.. | 3,572 | Medium clay loam.......... | .959 | 1.85 | May 9 | 23 | 2 | .808 | 1,379.4 |
| 72 | ...do.... | 3,572 | .....do.................... | .964 | 1.85 | ...do.... | 42 | 3 | 1.101 | 1,211.6 |
| 73 | ...do.... | 3,572 | .....do.................... | .968 | 1.85 | ...do.... | 51 | 4 | 1.327 | 1,742.8 |
| 74 | Potatoes | 3,572 | Medium clay loam.......... | .641 | 1.85 | May 13 | 63 | 3 | .876 | 6,302.6 |
| 75 | ...do.... | 3,572 | .....do.................... | .652 | 1.85 | ...do.... | 88 | 5 | 1.496 | 11,932.5 |
| 76 | ...do.... | 3,572 | .....do.................... | .636 | 1.85 | ...do.... | 97 | 6 | 2.046 | 12,932.3 |
| | | | | | | | | | | *Bushels.* |
| 77 | Oats.... | 3,572 | Medium clay loam.......... | 5.70 | 1.85 | May 12 | 64 | 3 | 1.401 | 43.3 |
| 78 | ...do.... | 3,572 | .....do.................... | 4.48 | 1.85 | May 17 | 60 | 4 | 1.766 | 54.6 |
| 79 | ...do.... | 3,572 | .....do.................... | 1.98 | 1.85 | May 19 | 59 | 4 | 2.486 | 73.7 |

TABLE III.—*Effects of different volumes of water on alfalfa, clover, and pasture during the season of 1910.*

| No. of plot. | Kind of crop. | Altitude. | Class of soil. | Area. | Precipitation April–September, inclusive. | Date of first irrigation. | Length of irrigation season. | Number of irrigations. | Total depth irrigation water applied. | Yield per acre. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Feet.* | | *Acres.* | *In.* | | *Days.* | | *Feet.* | *Tons.* |
| 1 | Alfalfa.. | 3,572 | Medium clay loam.......... | 0.983 | 1.85 | May 8 | 88 | 6 | 4.49 | 8.7 |
| 2 | Alfalfa.. | 3,572 | Medium clay loam.......... | 5.75 | 1.85 | May 7 | 43 | 2 | 1.306 | 3.30 |
| 3 | ...do.... | 3,572 | .....do.................... | 3.72 | 1.85 | May 9 | 79 | 3 | 1.872 | 3.56 |
| 4 | ...do.... | 3,572 | .....do.................... | 3.56 | 1.85 | May 10 | 78 | 3 | 2.104 | 4.74 |
| 5 | Alfalfa.. | 4,949 | Very gravelly............... | 10.65 | 2.36 | May 27 | 88 | 9 | 11.20 | 4.2 |
| 6 | Red clover. | 4,949 | Very gravelly............... | 3.31 | 2.36 | May 6 | 113 | 7 | 6.92 | 3.78 |
| 7 | ...do.... | 4,949 | .....do.................... | 4.32 | 2.36 | May 7 | 117 | 9 | 8.40 | 4.85 |
| 8 | ...do.... | 4,949 | .....do.................... | 3.98 | 2.36 | May 4 | 114 | 10 | 12.98 | 4.60 |
| 9 | Alfalfa.. | 4,949 | Very gravelly............... | 2.33 | 2.36 | May 3 | 101 | 4 | 6.352 | 3.78 |
| 10 | ...do.... | 4,949 | .....do.................... | 6.77 | 2.36 | May 2 | 105 | 6 | 6.925 | 3.65 |
| 11 | ...do.... | 4,949 | .....do.................... | 2.51 | 2.36 | Apr. 27 | 110 | 7 | 9.401 | 5.20 |

TABLE III.—*Effects of different volumes of water on alfalfa, clover, and pasture during the season of 1910*—Continued.

| No. of plot. | Kind of crop. | Altitude. | Class of soil. | Area. | Precipitation April-September, inclusive. | Date of first irrigation. | Length of irrigation season. | Number of irrigations. | Total depth irrigation water applied. | Yield per acre. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Feet.* | | *Acres.* | *In.* | | *Days.* | | *Feet.* | *Tons.* |
| 12 | Alfalfa.. | 4,742 | Uniform clay loam.......... | 3.20 | 2.36 | May 6 | 104 | 4 | 1.409 | 5.04 |
| 13 | ...do.... | 4,742 | .....do.................... | 3.16 | 2.36 | ...do.... | 102 | 6 | 1.953 | 3.41 |
| 14 | ...do.... | 4,742 | .....do.................... | 3.37 | 2.36 | ...do.... | 103 | 6 | 2.221 | 5.72 |
| 15 | Alfalfa.. | 4,497 | Very sandy................. | 3.38 | 2.23 | May 27 | 36 | 3 | 1.609 | 4.44 |
| 16 | ...do.... | 4,497 | .....do.................... | 4.15 | 2.23 | ...do.... | 50 | 5 | 2.649 | 4.28 |
| 17 | ...do.... | 4,497 | .....do.................... | 4.29 | 2.23 | ...do.... | 59 | 7 | 4.825 | 4.57 |
| 18 | Alfalfa.. | 2,367 | Impervious clay loam....... | 2.81 | 2.81 | Mar. 29 | 144 | 8 | 1.895 | 4.06 |
| 19 | ...do.... | 2,367 | .....do.................... | 3.69 | 2.81 | Mar. 27 | 143 | 8 | 2.848 | 3.66 |
| 20 | ...do.... | 2,367 | .....do.................... | 2.84 | 2.81 | Mar. 28 | 144 | 9 | 3.457 | 4.37 |
| 21 | Alfalfa.. | 2,482 | Impervious clay loam....... | 6.32 | 3.00 | May 7 | 115 | 7 | 1.434 | 2.85 |
| 22 | ...do.... | 2,482 | .....do.................... | 6.23 | 3.00 | May 5 | 120 | 7 | 2.112 | 4.93 |
| 23 | ...do.... | 2,482 | .....do.................... | 6.21 | 3.00 | ...do.... | 99 | 7 | 2.251 | 4.35 |
| 24 | Alfalfa.. | 2,607 | Uniform clay loam.......... | 5.08 | 2.80 | Apr. 28 | 109 | 6 | 2.821 | 5.15 |
| 25 | Alfalfa.. | 5,820 | Very gravelly.............. | 158.4 | 3.27 | .......... | 120 | .... | 21.13 | 3 to 3.5 |
| 26 | Alfalfa.. | 5,330 | Very gravelly.............. | 15.2 | 3.27 | .......... | 120 | .... | 16.00 | 3 to 4 |
| 27 | Alfalfa.. | 3,572 | Clay loam.................. | 51.0 | 1.85 | .......... | 140 | .... | 4.80 | 4 |
| 28 | Alfalfa.. | 3,572 | Uniform clay loam.......... | 31.8 | 1.85 | .......... | 140 | .... | 4.06 | 4 |
| 29 | Alfalfa and wheat. | 3,572 | Uniform clay loam.......... | 69.6 | 1.85 | .......... | 140 | .... | 4.00 | 4 |
| 30 | Alfalfa.. | 3,800 | Medium clay loam.......... | 2.92 | 3.04 | May 4 | 105 | 4 | 2.34 | 6.86 |
| 31 | ...do.... | 3,800 | .....do.................... | 2.89 | 3.04 | May 5 | 107 | 4 | 4.05 | 7.04 |
| 32 | ...do.... | 3,800 | .....do.................... | 3.38 | 3.04 | May 7 | 109 | 4 | 4.72 | 7.96 |

TABLE IV.—*Effects of different volumes of water on grains, orchards, and potatoes in Idaho during the season of 1911.*

| No. of plot. | Kind of crop. | Altitude. | Class of soil. | Area. | Precipitation April-September, inclusive. | Date of first irrigation. | Length of irrigation season. | Number of irrigations. | Total depth irrigation water applied. | Yield per acre. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Feet.* | | *Acres.* | *In.* | | *Days.* | | *Feet.* | *Bushels.* |
| 1 | Oats.... | 3,968 | Uniform sandy loam........ | 3.56 | 6.18 | July 12 | ...... | 1 | 0.453 | 29.5 |
| 2 | ...do.... | 3,968 | .....do.................... | 3.66 | 6.18 | June 21 | 26 | 2 | 1.144 | 45.9 |
| 3 | ...do.... | 3,968 | .....do.................... | 4.15 | 6.18 | June 17 | 42 | 3 | 1.889 | 50.8 |
| 4 | Wheat.. | 3,800 | Shallow clay loam.......... | 4.24 | 5.35 | June 11 | 15 | 2 | .864 | 30.6 |
| 5 | ...do.... | 3,800 | .....do.................... | 4.73 | 5.35 | June 7 | 43 | 3 | 1.623 | 33.8 |
| 6 | ...do.... | 3,800 | .....do.................... | 3.25 | 5.35 | June 5 | 51 | 4 | 2.153 | 38.0 |
| 7 | Wheat.. | 3,750 | Medium clay loam.......... | 3.59 | 5.50 | June 24 | 19 | 2 | .635 | 63.2 |
| 8 | ...do.... | 3,750 | .....do.................... | 7.49 | 5.50 | June 17 | 32 | 2 | 1.123 | 53.4 |
| 9 | ...do.... | 3,750 | .....do.................... | 5.42 | 5.50 | June 14 | 27 | 2 | 1.808 | 64.0 |
| 10 | Oats.... | 3,750 | Medium clay loam.......... | 5.80 | 5.50 | June 2 | 52 | 3 | 1.161 | 64.3 |
| 11 | ...do.... | 3,750 | .....do.................... | 4.82 | 5.50 | June 1 | 47 | 3 | 1.414 | 51.9 |
| 12 | ...do.... | 3,750 | .....do.................... | 7.02 | 5.50 | May 29 | 64 | 4 | 1.442 | 65.3 |
| 13 | Oats.... | 3,825 | Medium clay loam.......... | 4.01 | 3.19 | June 28 | ...... | 1 | .302 | 56.6 |
| 14 | ...do.... | 3,825 | .....do.................... | 6.10 | 3.19 | June 20 | 35 | 2 | 1.167 | 63.2 |
| 15 | ...do.... | 3,825 | .....do.................... | 4.03 | 3.19 | June 8 | 53 | 3 | 2.266 | 68.9 |

TABLE IV.—*Effects of different volumes of water on grains, orchards, and potatoes in Idaho during the season of 1911*—Continued.

| No. of plot. | Kind of crop. | Altitude. | Class of soil. | Area. | Precipitation April–September, inclusive. | Date of first irrigation. | Length of irrigation season. | Number of irrigations. | Total depth irrigation water applied. | Yield per acre. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Feet.* | | *Acres.* | *In.* | | *Days.* | | *Feet.* | *Bushels.* |
| 16 | Orchard. | 3,825 | Medium clay loam | 4.58 | 3.19 | July 6 | ...... | 1 | .268 | (1) |
| 17 | Fall rye. | 3,700 | Very sandy loam | 6.89 | 5.30 | May 12 | ...... | 1 | .729 | 11.6 |
| 18 | Oats | 3,700 | Very sandy loam | 4.29 | 5.30 | June 8 | 45 | 3 | .656 | 23.3 |
| 19 | ...do | 3,700 | ...do | 4.01 | 5.30 | June 6 | 43 | 3 | .888 | 26.0 |
| 20 | ...do | 3,700 | ...do | 4.17 | 5.30 | June 1 | 54 | 4 | 1.047 | 35.0 |
| 21 | Potatoes | 3,700 | Extremely sandy | 2.89 | 5.30 | July 12 | 40 | 3 | .613 | 112.8 |
| 22 | ...do | 3,700 | ...do | 2.90 | 5.30 | June 19 | 46 | 3 | .955 | 108.1 |
| 23 | ...do | 3,700 | ...do | 3.27 | 5.30 | June 22 | 59 | 4 | 1.062 | 128.1 |
| 24 | Oats | 4,100 | Deep clay loam | 4.98 | 5.80 | June 25 | ...... | 1 | .641 | 76.5 |
| 25 | ...do | 4,100 | ...do | 5.11 | 5.80 | June 22 | ...... | 1 | 1.316 | 73.5 |
| 26 | ...do | 4,100 | ...do | 4.42 | 5.80 | June 15 | ...... | 1 | 1.654 | 72.4 |
| 27 | Wheat | 4,949 | Very gravelly | 15.51 | 6.95 | July 3 | 49 | 3 | 1.377 | 20.9 |
| 28 | Wheat | 4,949 | Shallow sandy loam | 14.91 | 6.95 | June 16 | 53 | 3 | 5.342 | 30.0 |
| 29 | Potatoes | 4,949 | Sandy loam | 7.11 | 6.95 | July 20 | 46 | 4 | 2.828 | 211.8 |
| 30 | Wheat | 4,949 | Shallow sandy loam | 9.83 | 6.95 | June 20 | 42 | 3 | 3.466 | 31.6 |
| 31 | Oats | 4,949 | Sandy loam | 3.85 | 6.95 | July 16 | 36 | 3 | 4.511 | 31.8 |
| 32 | ...do | 4,949 | ...do | 2.55 | 6.95 | June 30 | 54 | 4 | 5.943 | 68.4 |
| 33 | ...do | 4,949 | ...do | 2.96 | 6.95 | June 28 | 53 | 5 | 10.366 | 57.2 |
| 34 | Wheat | 2,600 | Impervious clay loam | 8.47 | 4.09 | June 1 | 39 | 2 | .307 | 19.7 |
| 35 | ...do | 2,600 | ...do | 11.05 | 4.09 | June 7 | ...... | 1 | .315 | 16.0 |
| 36 | ...do | 2,600 | ...do | 8.64 | 4.09 | June 5 | 38 | 3 | .589 | 22.0 |
| 37 | Wheat | 2,600 | Impervious clay loam | 2.05 | 4.09 | June 25 | 19 | 3 | .263 | 12.0 |
| 38 | ...do | 2,600 | ...do | 1.19 | 4.09 | June 26 | 15 | 2 | .271 | 5.0 |
| 39 | ...do | 2,600 | ...do | 1.65 | 4.09 | June 25 | 22 | 3 | .497 | 5.0 |
| 40 | Oats | 2,600 | Impervious clay loam | 3.06 | 4.09 | June 24 | 18 | 2 | .294 | 22.0 |
| 41 | ...do | 2,600 | ...do | 2.08 | 4.09 | June 23 | 21 | 3 | .372 | 26.0 |
| 42 | ...do | 2,600 | ...do | 2.60 | 4.09 | June 24 | 23 | 3 | .417 | 26.0 |
| 43 | Oats | 2,600 | Sandy loam | 5.38 | 4.09 | May 30 | ...... | 1 | .185 | 16.0 |
| 44 | ...do | 2,600 | ...do | 7.29 | 4.09 | May 24 | ...... | 1 | .199 | 10.6 |
| 45 | ...do | 2,600 | ...do | 6.25 | 4.09 | June 3 | ...... | 1 | .248 | 17.7 |
| 46 | Oats | 2,607 | Impervious clay loam | 4.56 | 6.80 | June 12 | 25 | 2 | .557 | 28.0 |
| 47 | ...do | 2,607 | ...do | 1.35 | 6.80 | ...do | 25 | 2 | .618 | 34.8 |
| 48 | ...do | 2,607 | ...do | 3.69 | 6.80 | June 13 | 24 | 2 | .769 | 31.4 |
| 49 | Oats | 2,460 | Clay loam | 2.58 | 6.80 | June 2 | 28 | 2 | .461 | 43.0 |
| 50 | ...do | 2,460 | ...do | 2.30 | 6.80 | June 4 | 38 | 3 | .698 | 63.0 |
| 51 | ...do | 2,460 | ...do | 2.37 | 6.80 | June 3 | 39 | 3 | 1.076 | 73.0 |
| 52 | Wheat | 2,607 | Sandy loam | 2.56 | 6.80 | June 8 | 23 | 2 | 1.193 | 49.0 |
| 53 | Wheat | 2,607 | ...do | 6.17 | 6.80 | June 8 | 38 | 3 | 1.371 | 35.5 |
| 54 | ...do | 2,607 | ...do | 5.79 | 6.80 | ...do | 23 | 2 | 1.428 | 37.6 |
| 55 | Wheat | 2,460 | Sandy loam mixedwith clay | 4.40 | 6.80 | June 27 | 19 | 2 | .770 | 45.4 |
| 56 | ...do | 2,460 | ...do | 5.55 | 6.80 | June 25 | 19 | 2 | 1.367 | 49.5 |
| 57 | Oats | 2,547 | Sandy loam | 6.72 | 6.80 | June 12 | 35 | 3 | 1.258 | 47.3 |
| 58 | ...do | 2,547 | ...do | 4.16 | 6.80 | June 7 | 32 | 2 | 1.315 | 59.3 |
| 59 | ...do | 2,547 | ...do | 5.67 | 6.80 | June 5 | 32 | 3 | 3.095 | 54.1 |
| 60 | Wheat | 2,400 | Coarse sandy loam | 3.74 | 6.80 | June 9 | 33 | 2 | .866 | 27.8 |
| 61 | ...do | 2,400 | ...do | 6.21 | 6.80 | ...do | 34 | 3 | 1.186 | 43.96 |
| 62 | ...do | 2,400 | ...do | 4.14 | 6.80 | June 10 | 34 | 3 | 1.253 | 33.59 |

[1] Four years old, no crop.

TABLE IV.—*Effects of different volumes of water on grains, orchards, and potatoes in Idaho during the season of 1911*—Continued.

| No. of plot. | Kind of crop. | Altitude. | Class of soil. | Area. | Precipitation April-September, inclusive. | Date of first irrigation. | Length of irrigation season. | Number of irrigations. | Total depth irrigation water applied. | Yield per acre. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Feet.* | | *Acres.* | *In.* | | *Days.* | | *Feet.* | *Bushels.* |
| 63 | Oats | 5,330 | Very gravelly | 4.03 | 6.18 | July 15 | 18 | 2 | 3.187 | 45.6 |
| 64 | ...do | 5,330 | .....do | 8.63 | 6.18 | July 12 | 20 | 2 | 4.280 | 39.9 |
| 65 | ...do | 5,330 | .....do | 5.55 | 6.18 | June 23 | 38 | 3 | 6.304 | 40.9 |
| 66 | Orchard | 2,460 | Clay loam | 35.00 | 6.80 | .......... | 122 | .... | 4.25 | (1) |
| 67 | Orchard | 2,547 | Coarse sandy loam | 13.15 | 6.80 | .......... | 122 | .... | 5.26 | (1) |
| 68 | Orchard | 2,641 | Clay loam | 31.85 | 6.80 | .......... | 122 | .... | 3.56 | (1) |
| 69 | Orchard | 2,641 | Clay loam | 39.72 | 6.80 | .......... | 122 | .... | 2.32 | (1) |
| 70 | Grain and alfalfa. | 5,330 | Very gravelly | 35.59 | 6.18 | June 13 | 71 | .... | 9.484 | [2] 3<br>[3] 30 |
| | | | | | | | | | | *Bushels.* |
| 71 | Oats | 2,600 | Impervious clay loam | 2.02 | 4.09 | May 11 | 64 | 4 | .525 | 11.0 |
| 72 | ...do | 2,600 | .....do | 2.03 | 4.09 | May 13 | 59 | 5 | .825 | 31.0 |
| 73 | ...do | 2,600 | .....do | 2.03 | 4.09 | May 12 | 61 | 5 | .967 | 33.5 |
| | | | | | | | | | | *Tons.* |
| 74 | Corn | 3,700 | Extremely sandy | 3.91 | 5.30 | June 20 | 54 | 3 | .789 | 4.00 |
| 75 | ...do | 3,700 | .....do | 4.34 | 5.30 | June 22 | 57 | 3 | .789 | 4.00 |
| 76 | ...do | 3,700 | .....do | 4.66 | 5.30 | June 20 | 57 | 3 | 1.381 | 4.00 |
| | | | | | | | | | | *Pounds.* |
| 77 | Wheat | 3,572 | Medium clay loam | .189 | 3.98 | .......... | ...... | 0 | .000 | 952.37 |
| 78 | ...do | 3,572 | .....do | .092 | 3.98 | June 1 | ...... | 1 | .479 | 1,108.69 |
| 79 | ...do | 3,572 | .....do | .096 | 3.98 | June 2 | 41 | 3 | 1.285 | 1,322.91 |
| 80 | ...do | 3,572 | .....do | .097 | 3.98 | ...do | 42 | 5 | 1.516 | 1,371.13 |
| 81 | ...do | 3,572 | .....do | .092 | 3.98 | ...do | 48 | 4 | 1.737 | 1,565.21 |
| 82 | ...do | 3,572 | .....do | .091 | 3.98 | ...do | 55 | 7 | 2.558 | 1,472.53 |
| 83 | ...do | 3,572 | .....do | .092 | 3.98 | June 3 | 54 | 10 | 2.820 | 1,021.73 |
| 84 | Wheat | 3,572 | Medium clay loam | .189 | 3.98 | .......... | ...... | 0 | .000 | 973.54 |
| 85 | ...do | 3,572 | .....do | .094 | 3.98 | June 1 | ...... | 1 | .379 | 1,095.74 |
| 86 | ...do | 3,572 | .....do | .093 | 3.98 | June 2 | 42 | 3 | 1.184 | 1,193.54 |
| 87 | ...do | 3,572 | .....do | .095 | 3.98 | ...do | 48 | 4 | 1.374 | 1,389.47 |
| 88 | ...do | 3,572 | .....do | .092 | 3.98 | ...do | 42 | 5 | 1.861 | 1,130.43 |
| 89 | ...do | 3,572 | .....do | .094 | 3.98 | ...do | 55 | 7 | 2.853 | 1,351.06 |
| 90 | ...do | 3,572 | .....do | .094 | 3.98 | June 3 | 54 | 10 | 3.156 | 797.87 |
| 91 | Wheat | 3,572 | Medium clay loam | .189 | 3.98 | .......... | ...... | 0 | .000 | 1,063.49 |
| 92 | ...do | 3,572 | .....do | .091 | 3.98 | June 1 | ...... | 1 | .417 | 1,285.71 |
| 93 | ...do | 3,572 | .....do | .093 | 3.98 | June 2 | 42 | 3 | 1.148 | 1,709.67 |
| 94 | ...do | 3,572 | .....do | .090 | 3.98 | ...do | 48 | 4 | 1.451 | 1,833.33 |
| 95 | ...do | 3,572 | .....do | .094 | 3.98 | ...do | 42 | 5 | 1.842 | 1,563.83 |
| 96 | ...do | 3,572 | .....do | .093 | 3.98 | June 3 | 54 | 7 | 2.161 | 1,139.78 |
| 97 | ...do | 3,572 | .....do | .096 | 3.98 | ...do | 54 | 10 | 2.834 | 968.75 |
| 98 | Oats | 3,572 | Medium clay loam | .63 | 3.98 | June 16 | ...... | 1 | .376 | 1,333.33 |
| 99 | ...do | 3,752 | .....do | .63 | 3.98 | June 10 | 30 | 3 | .962 | 1,501.58 |
| 100 | ...do | 3,752 | .....do | .61 | 3.98 | June 6 | 42 | 5 | 1.533 | 1,670.49 |
| 101 | Wheat | 3,572 | Medium clay loam | .990 | 3.98 | June 9 | ...... | 1 | .460 | 1,719.19 |
| 102 | ...do | 3,572 | .....do | .982 | 3.98 | June 5 | 17 | 2 | 1.009 | 1,450.10 |
| 103 | ...do | 3,572 | .....do | .982 | 3.98 | June 3 | 34 | 4 | 1.402 | 1,446.02 |
| 104 | Barley | 3,572 | Medium clay loam | .985 | 3.98 | June 21 | ...... | 1 | .555 | 1,470.05 |
| 105 | ...do | 3,572 | .....do | .965 | 3.98 | June 18 | 20 | 2 | .953 | 1,842.48 |
| 106 | ...do | 3,572 | .....do | .951 | 3.98 | June 17 | 30 | 3 | 1.678 | 1,590.95 |
| 107 | Wheat | 3,572 | Medium clay loam | .610 | 3.98 | June 15 | ...... | 1 | .419 | 1,754.09 |
| 108 | ...do | 3,572 | .....do | .622 | 3.98 | June 13 | 34 | 3 | .909 | 1,860.12 |
| 109 | ...do | 3,572 | .....do | .641 | 3.98 | June 14 | 40 | 5 | 1.788 | 1,893.91 |
| 110 | Potatoes | 3,572 | Medium clay loam | .630 | 3.98 | July 9 | ...... | 1 | .539 | 7,349.2 |
| 111 | ...do | 3,572 | .....do | .630 | 3.98 | July 2 | 40 | 5 | 2.208 | 16,738.0 |
| 112 | ...do | 3,572 | .....do | .610 | 3.98 | June 29 | 41 | 5 | 3.644 | 16,754.0 |

[1] Yield not measured. [2] Tons alfalfa. [3] Bushels oats.

TABLE V.—*Effects of different volumes of water on alfalfa, clover, and pasture during the season of 1911.*

| No. of plot. | Kind of crop. | Altitude. | Class of soil. | Area. | Precipitation April–September, inclusive. | Date of first irrigation. | Length of irrigation season. | Number of irrigations. | Total depth irrigation water applied. | Yield per acre. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Feet.* | | *Acres.* | *In.* | | *Days.* | | *Feet.* | *Pounds.* |
| 1 | Alfalfa.. | 3,572 | Medium clay loam.......... | 0.943 | 3.98 | May 10 | 105 | 3 | 1.775 | 7,534.0 |
| 2 | ...do..... | 3,572 | .....do.................... | .930 | 3.98 | ...do..... | 128 | 6 | 3.329 | 10,608.0 |
| 3 | ...do..... | 3,572 | .....do.................... | .965 | 3.98 | May 11 | 128 | 8 | 4.000 | 13,233.0 |
| | | | | | | | | | | *Tons.* |
| 4 | Alfalfa.. | 3,800 | Shallow clay loam.......... | 4.69 | 5.35 | May 9 | 109 | 4 | 1.962 | 5.83 |
| 5 | ...do..... | 3,800 | .....do.................... | 5.38 | 5.35 | May 12 | 116 | 6 | 2.327 | 5.57 |
| 6 | ...do..... | 3,800 | .....do.................... | 3.85 | 5.35 | May 8 | 108 | 5 | 2.549 | 5.25 |
| 7 | Alfalfa.. | 3,750 | Medium clay loam.......... | 3.72 | 5.35 | May 31 | 86 | 4 | 2.677 | 4.56 |
| 8 | ...do..... | 3,750 | .....do.................... | 2.67 | 5.35 | May 21 | 95 | 5 | 3.263 | 6.00 |
| 9 | ...do..... | 3,750 | .....do.................... | 3.76 | 5.35 | May 19 | 119 | 6 | 3.786 | 6.00 |
| 10 | Alfalfa.. | 3,800 | Medium clay loam.......... | 4.17 | 3.19 | May 4 | 80 | 2 | 1.286 | 6.1 |
| 11 | ...do..... | 3,800 | .....do.................... | 4.22 | 3.19 | May 6 | 135 | 4 | 3.194 | 6.4 |
| 12 | ...do..... | 3,800 | .....do.................... | 4.96 | 3.19 | May 8 | 135 | 5 | 3.981 | 5.76 |
| 13 | Alfalfa.. | 3,825 | Medium clay loam.......... | 4.37 | 3.19 | May 17 | 105 | 3 | 1.309 | 4.73 |
| 14 | ...do..... | 3,825 | .....do.................... | 4.19 | 3.19 | May 13 | 112 | 4 | 2.767 | 5.44 |
| 15 | ...do..... | 3,825 | .....do.................... | 4.78 | 3.19 | May 14 | 106 | 5 | 3.211 | 4.97 |
| 16 | Alfalfa.. | 3,700 | Very sandy loam........... | 2.65 | 5.30 | May 10 | 119 | 6 | 1.894 | 1.50 |
| 17 | ...do..... | 3,700 | .....do.................... | 1.80 | 5.30 | May 4 | 125 | 6 | 2.611 | 2.74 |
| 18 | Alfalfa.. | 4,100 | Deep clay loam............. | 9.98 | 5.80 | May 20 | ...... | 1 | .993 | 3.1 |
| 19 | Alfalfa.. | 4,949 | Very gravelly.............. | 10.65 | 6.95 | May 19 | 108 | 8 | 11.532 | 4.54 |
| 20 | Alfalfa.. | 4,949 | Very gravelly.............. | 5.45 | 6.95 | May 22 | 77 | 4 | 5.402 | 1.99 |
| 21 | ...do..... | 4,949 | .....do.................... | 5.28 | 6.95 | May 23 | 94 | 7 | 6.400 | 3.42 |
| 22 | ...do..... | 4,949 | .....do.................... | 5.73 | 6.95 | May 22 | 94 | 6 | 7.224 | 3.27 |
| 23 | Clover.. | 4,949 | Very gravelly.............. | 3.31 | 6.95 | May 20 | 88 | 5 | 5.246 | 2.69 |
| 24 | ...do..... | 4,949 | .....do.................... | 4.32 | 6.95 | ...do..... | 103 | 7 | 6.611 | 3.25 |
| 25 | ...do..... | 4,949 | .....do.................... | 3.98 | 6.95 | May 19 | 109 | 9 | 14.721 | 2.91 |
| 26 | Alfalfa.. | 2,607 | Clay loam.................. | 3.37 | 6.80 | June 3 | 103 | 7 | 1.535 | [1].1 |
| 27 | ...do..... | 2,607 | .....do.................... | 3.48 | 6.80 | ...do..... | 103 | 8 | 2.912 | [1].1 |
| 28 | ...do..... | 2,607 | .....do.................... | 3.37 | 6.80 | ...do..... | 103 | 8 | 4.114 | [1].89 |
| 29 | Alfalfa.. | 2,607 | Impervious clay loam....... | 4.94 | 6.80 | Apr. 26 | 141 | 9 | 2.136 | 2.11 |
| 30 | ...do..... | 2,607 | .....do.................... | 4.21 | 6.80 | Apr. 25 | 142 | 11 | 3.511 | 3.93 |
| 31 | ...do..... | 2,607 | .....do.................... | 9.39 | 6.80 | ...do..... | 141 | 12 | 3.814 | 4.39 |
| 32 | Timothy and clover. | 2,547 | Dark sandy loam............ | 5.43 | 6.80 | Apr. 21 | 122 | 7 | 3.257 | 4.63 |
| 33 | ...do..... | 2,547 | .....do.................... | 5.46 | 6.80 | Apr. 26 | 119 | 8 | 4.437 | 4.57 |
| 34 | ...do..... | 2,547 | .....do.................... | 4.53 | 6.80 | Apr. 25 | 119 | 9 | 6.040 | 3.84 |
| 35 | Alfalfa and grain. | 5,820 | Very gravelly.............. | 156.3 | 6.18 | June 11 | 67 | .... | 10.91 | 3.00 |
| 36 | Alfalfa.. | 5,330 | Very gravelly.............. | 40.49 | 6.18 | June 15 | 65 | .... | 8.562 | 3.00 |

[1] New seeding, first year.

TABLE VI.—*Effects of different volumes of water on grains, orchards, and potatoes in Idaho during the season of 1912.*

| No. of plot. | Kind of crop. | Altitude. | Class of soil. | Area. | Precipitation, April–September, inclusive. | Date of first irrigation. | Length of irrigation season. | Number of irrigations. | Total depth irrigation water applied. | Yield per acre. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Feet.* | | *Acres.* | *In.* | | *Days.* | | *Feet.* | *Bushels.* |
| 1 | Wheat.. | 3,800 | Medium clay loam.......... | 2.37 | 3.71 | June 21 | ...... | 1 | 0.735 | 67.5 |
| 2 | ...do.... | 3,800 | .....do.................. | 6.54 | 3.71 | June 24 | ...... | 1 | .871 | 72.1 |
| 3 | ...do.... | 3,800 | .....do.................. | 8.27 | 3.71 | June 18 | 36 | 2 | 1.158 | 82.9 |
| 4 | Orchard. | 3,825 | Medium clay loam.......... | 4.58 | 3.71 | Aug. 1 | ...... | 1 | .143 | (1) |
| 5 | Wheat.. | 4,000 | Shallow gravelly............ | 5.68 | 3.71 | June 7 | 22 | 2 | .927 | 31.16 |
| 6 | ...do.... | 4,000 | Clay...................... | 7.72 | 3.71 | June 9 | 35 | 3 | 1.436 | 37.65 |
| 7 | ...do.... | 4,000 | .....do.................. | 4.16 | 3.71 | June 6 | 51 | 4 | 1.598 | 28.60 |
| 8 | Oats.... | 4,000 | Shallow clay loam........... | 1.83 | 3.71 | June 5 | 39 | 2 | .487 | 10.92 |
| 9 | ...do.... | 4,000 | .....do.................. | 3.86 | 3.71 | June 3 | 53 | 3 | 1.427 | 25.90 |
| 10 | ...do.... | 4,000 | .....do.................. | 3.23 | 3.71 | June 1 | 57 | 4 | 1.748 | 24.76 |
| 11 | Wheat.. | 3,800 | Shallow clay loam........... | 6.91 | 3.81 | June 26 | ...... | 1 | .276 | 15.92 |
| 12 | ...do.... | 3,800 | .....do.................. | 6.05 | 3.81 | June 18 | 37 | 2 | .791 | 18.02 |
| 13 | ...do.... | 3,800 | .....do.................. | 6.09 | 3.81 | June 23 | 34 | 3 | 1.214 | 24.11 |
| 14 | Wheat.. | 3,750 | Deep clay loam............. | 4.85 | 3.81 | June 3 | 39 | 2 | .967 | 39.59 |
| 15 | ...do.... | 3,750 | .....do.................. | 4.41 | 3.81 | June 4 | 60 | 3 | 1.655 | 43.76 |
| 16 | ...do.... | 3,750 | .....do.................. | 4.78 | 3.81 | June 2 | 61 | 3 | 2.053 | 42.05 |
| 17 | Orchard. | 3,800 | Shallow clay loam........... | 8.40 | 3.81 | July 12 | ...... | 1 | .093 | (1) |
| | | | | | | | | | | *Pounds.* |
| 18 | Wheat.. | 2,763 | Impervious clay loam...... | .153 | 8.25 | ........... | ...... | 0 | .000 | 784.3 |
| 19 | ...do.... | 2,763 | .....do.................. | .170 | 8.25 | June 25 | ...... | 1 | .344 | 1,058.81 |
| 20 | ...do.... | 2,763 | .....do.................. | .184 | 8.25 | ...do.... | 9 | 2 | .529 | 1,304.32 |
| 21 | ...do.... | 2,763 | .....do.................. | .173 | 8.25 | June 12 | 22 | 3 | .690 | 1,734.09 |
| 22 | ...do.... | 2,763 | .....do.................. | .161 | 8.25 | ...do.... | 36 | 4 | .950 | 1,863.33 |
| 23 | ...do.... | 2,763 | .....do.................. | .178 | 8.25 | ...do.... | 36 | 4 | .862 | 2,022.48 |
| 24 | ...do.... | 2,763 | .....do.................. | .165 | 8.25 | ...do.... | 43 | 5 | 1.042 | 3,272.72 |
| | | | | | | | | | | *Bushels.* |
| 25 | Wheat.. | 2,607 | Impervious clay loam...... | 3.98 | 8.25 | June 5 | 39 | 2 | .780 | 34.92 |
| 26 | ...do.... | 2,607 | .....do.................. | 1.42 | 8.25 | June 7 | 51 | 3 | .951 | 37.32 |
| 27 | ...do.... | 2,607 | .....do.................. | 3.57 | 8.25 | June 3 | 54 | 4 | 1.186 | 38.38 |
| 28 | Wheat.. | 2,607 | Clay loam.................. | 13.36 | 8.25 | June 19 | 30 | 2 | 2.473 | 31.81 |
| 29 | Oats.... | 4,949 | Very gravelly............... | 5.40 | 8.51 | June 28 | 40 | 3 | 2.953 | 76.7 |
| 30 | ...do.... | 4,949 | .....do.................. | 5.52 | 8.51 | June 29 | 48 | 3 | 3.236 | 63.0 |
| 31 | ...do.... | 4,949 | .....do.................. | 5.73 | 8.51 | June 28 | 49 | 3 | 4.263 | 74.7 |
| | | | | | | | | | | *Pounds.* |
| 32 | Wheat.. | 3,572 | Medium clay loam.......... | .689 | 3.47 | May 29 | ...... | 1 | .638 | 2,367.3 |
| 33 | ...do.... | 3,572 | .....do.................. | .636 | 3.47 | May 28 | 23 | 2 | 1.087 | 2,336.1 |
| 34 | ...do.... | 3,572 | .....do.................. | .625 | 3.47 | May 27 | 30 | 4 | 1.653 | 2,326.7 |
| 35 | Wheat.. | 3,572 | Medium clay loam.......... | .186 | 3.47 | ........... | ...... | 0 | .000 | 1,087.7 |
| 36 | ...do.... | 3,572 | .....do.................. | .097 | 3.47 | June 3 | ...... | 1 | .589 | 1,104.2 |
| 37 | ...do.... | 3,572 | .....do.................. | .088 | 3.47 | ...do.... | 30 | 3 | 1.244 | 1,530.6 |
| 38 | ...do.... | 3,572 | .....do.................. | .094 | 3.47 | June 4 | 28 | 4 | 1.475 | 1,525.4 |
| 39 | ...do.... | 3,572 | .....do.................. | .091 | 3.47 | ...do.... | 44 | 6 | 1.806 | 1,444.3 |
| 40 | ...do.... | 3,572 | .....do.................. | .093 | 3.47 | ...do.... | 44 | 7 | 2.381 | 1,652.3 |
| 41 | ...do.... | 3,572 | .....do.................. | .089 | 3.47 | ...do.... | 52 | 10 | 2.638 | 2,022.3 |
| 42 | Wheat.. | 3,572 | Medium clay loam.......... | .186 | 3.47 | ........... | ...... | 0 | .000 | 912.7 |
| 43 | ...do.... | 3,572 | .....do.................. | .091 | 3.47 | June 3 | ...... | 1 | .343 | 1,207.2 |
| 44 | ...do.... | 3,572 | .....do.................. | .092 | 3.47 | ...do.... | 29 | 3 | 1.190 | 1,207.8 |
| 45 | ...do.... | 3,572 | .....do.................. | .088 | 3.47 | June 4 | 28 | 4 | 1.179 | 1,775.6 |
| 46 | ...do.... | 3,572 | .....do.................. | .094 | 3.47 | ...do.... | 44 | 6 | 2.125 | 1,483.0 |
| 47 | ...do.... | 3,572 | .....do.................. | .090 | 3.47 | ...do.... | 44 | 7 | 2.216 | 1,770.9 |
| 48 | ...do.... | 3,572 | .....do.................. | .097 | 3.47 | ...do.... | 52 | 10 | 2.798 | 1,780.2 |
| 49 | Wheat.. | 3,572 | Medium clay loam.......... | .183 | 3.47 | ........... | ...... | 0 | .000 | 1,042.5 |
| 50 | ...do.... | 3,572 | .....do.................. | .094 | 3.47 | June 3 | ...... | 1 | .481 | 1,122.8 |
| 51 | ...do.... | 3,572 | .....do.................. | .090 | 3.47 | ...do.... | 29 | 3 | 1.273 | 1,407.8 |
| 52 | ...do.... | 3,572 | .....do.................. | .092 | 3.47 | June 4 | 29 | 4 | 1.272 | 1,469.0 |
| 53 | ...do.... | 3,572 | .....do.................. | .086 | 3.47 | ...do.... | 44 | 6 | 1.815 | 1,586.9 |
| 54 | ...do.... | 3,572 | .....do.................. | .094 | 3.47 | ...do.... | 45 | 7 | 2.146 | 1,536.0 |
| 55 | ...do.... | 3,572 | .....do.................. | .084 | 3.47 | ...do.... | 52 | 10 | 2.436 | 1,846.0 |

[1] Only 5 years old, small yield not measured.

TABLE VI.—*Effects of different volumes of water on grains, orchards, and potatoes in Idaho during the season of 1912*—Continued.

| No. of plot. | Kind of crop. | Altitude. | Class of soil. | Area. | Precipitation, April–September, inclusive. | Date of first irrigation. | Length of irrigation season. | Number of irrigations. | Total depth irrigation water applied. | Yield per acre. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Feet.* | | *Acres.* | *In.* | | *Days.* | | *Feet.* | *Pounds.* |
| 56 | Oats | 3,572 | Medium clay loam | .383 | 3.47 | June 6 | ...... | 1 | 0.418 | 2,362.3 |
| 57 | ...do | 3,572 | ...do | .378 | 3.47 | ...do | 36 | 3 | .857 | 2,992.3 |
| 58 | ...do | 3,572 | ...do | .383 | 3.47 | June 4 | 43 | 5 | 1.267 | 3,333.3 |
| 59 | ...do | 3,572 | ...do | .390 | 3.47 | June 5 | 49 | 7 | 1.577 | 3,264.9 |
| 60 | ...do | 3,572 | ...do | .334 | 3.47 | June 4 | 50 | 9 | 2.036 | 3,830.5 |
| 61 | Barley | 3,572 | Medium clay loam | .325 | 3.47 | June 11 | ...... | 1 | .434 | 2,505.3 |
| 62 | ...do | 3,572 | ...do | .326 | 3.47 | ...do | 29 | 3 | 1.061 | 4,074.1 |
| 63 | ...do | 3,572 | ...do | .312 | 3.47 | June 12 | 37 | 5 | 1.521 | 4,320.5 |
| 64 | Potatoes | 3,572 | Medium clay loam | .627 | 3.47 | July 1 | 17 | 2 | .541 | 12,135.0 |
| 65 | ...do | 3,572 | ...do | .628 | 3.47 | June 30 | 44 | 5 | 1.943 | 18,613.0 |
| 66 | ...do | 3,572 | ...do | .636 | 3.47 | June 29 | 53 | 7 | 2.516 | 16,681.0 |

TABLE VII.—*Effects of different volumes of water on alfalfa during the season of 1912.*

| No. of plot. | Kind of crop. | Altitude. | Class of soil. | Area. | Precipitation April–September, inclusive. | Date of first irrigation. | Length of irrigation season. | Number of irrigations. | Total depth irrigation water applied. | Yield per acre. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Feet.* | | *Acres.* | *In.* | | *Days.* | | *Feet.* | *Pounds.* |
| 1 | Alfalfa | 3,572 | Medium clay loam | 0.372 | 3.47 | May 27 | 44 | 2 | 0.615 | 5,695.0 |
| 2 | ...do | 3,572 | ...do | .585 | 3.47 | May 14 | 65 | 4 | 1.308 | 8,003.0 |
| 3 | ...do | 3,572 | ...do | .372 | 3.47 | ...do | 78 | 7 | 2.059 | 10,828.0 |
| 4 | ...do | 3,572 | ...do | .569 | 3.47 | ...do | 84 | 9 | 2.533 | 11,317.0 |
| 5 | ...do | 3,572 | ...do | .369 | 3.47 | ...do | 88 | 11 | 2.931 | 12,506.0 |
| 6 | ...do | 3,572 | ...do | .580 | 3.47 | May 15 | 86 | 13 | 4.003 | 12,612.0 |
| | | | | | | | | | | *Tons.* |
| 7 | Alfalfa | 3,800 | Medium clay loam | 6.02 | 3.71 | May 22 | 95 | 3 | 1.708 | 5.94 |
| 8 | ...do | 3,800 | ...do | 7.49 | 3.71 | May 24 | 90 | 3 | 2.070 | 5.84 |
| 9 | ...do | 3,800 | ...do | 7.71 | 3.71 | May 16 | 123 | 6 | 3.381 | 5.70 |
| 10 | Alfalfa | 3,800 | Shallow clay loam | 4.24 | 3.81 | May 14 | 107 | 7 | 2.339 | 6.44 |
| 11 | ...do | 3,800 | ...do | 3.38 | 3.81 | ...do | 107 | 6 | 2.513 | 5.90 |
| 12 | ...do | 3,800 | ...do | 3.75 | 3.81 | May 13 | 107 | 9 | 3.153 | 7.04 |
| 13 | Alfalfa | 3,750 | Deep clay loam | 4.74 | 3.81 | May 31 | 97 | 3 | 1.064 | 4.67 |
| 14 | ...do | 3,750 | ...do | 4.82 | 3.81 | May 24 | 92 | 4 | 1.589 | 4.42 |
| 15 | ...do | 3,750 | ...do | 5.28 | 3.81 | ...do | 100 | 4 | 1.799 | 4.80 |
| 16 | Alfalfa | 3,800 | Shallow clay loam | 14.28 | 3.81 | May 27 | 98 | 4 | 2.413 | 6.00 |
| 17 | Alfalfa | 2,607 | Clay loam | 4.77 | 8.25 | May 17 | 101 | 6 | 1.870 | 4.31 |
| 18 | ...do | 2,607 | ...do | 3.62 | 8.25 | May 16 | 98 | 6 | 2.961 | 4.11 |
| 19 | ...do | 2,607 | ...do | 6.10 | 8.25 | May 19 | 105 | 7 | 2.887 | 3.89 |
| 20 | Alfalfa | 4,949 | Porous gravelly | 4.36 | 8.51 | May 31 | 75 | 5 | 1.983 | 2.52 |
| 21 | ...do | 4,949 | ...do | 4.94 | 8.51 | June 21 | 55 | 3 | 2.027 | 1.48 |
| 22 | ...do | 4,949 | ...do | 4.75 | 8.51 | June 1 | 75 | 6 | 2.582 | 1.58 |
| 23 | Alfalfa | 4,949 | Porous gravelly | 3.68 | 8.51 | June 4 | 71 | 4 | 3.047 | 1.82 |
| 24 | ...do | 4,949 | ...do | 2.65 | 8.51 | June 5 | 71 | 4 | 3.307 | 2.00 |
| 25 | ...do | 4,949 | ...do | 2.13 | 8.51 | June 4 | 71 | 4 | 6.721 | 2.50 |

TABLE VIII.—*Effects of different volumes of water on grains, alfalfa, orchards, potatoes, and sugar beets during the season of 1913.*

| No. of plot. | Kind of crop. | Altitude. | Class of soil. | Area. | Precipitation April–September, inclusive. | Date of first irrigation. | Length of irrigation season. | Number of irrigations. | Total depth irrigation water applied. | Yield per acre. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Feet.* | | *Acres.* | *In.* | | *Days.* | | *Feet.* | *Tons.* |
| 1 | Alfalfa.. | 4,500 | Clay loam.................. | 2.70 | 7.35 | May 31 | 90 | 3 | 1.2850 | 3.06 |
| 2 | ...do..... | 4,500 | .....do..................... | 3.45 | 7.35 | ...do..... | 87 | 4 | 1.9607 | 2.51 |
| 3 | ...do..... | 4,500 | .....do..................... | 3.44 | 7.35 | May 30 | 89 | 6 | 2.6876 | 3.03 |
| | | | | | | | | | | *Bushels.* |
| 4 | Big "4" oats. | 4,550 | Clay loam.................. | 5.08 | 7.35 | July 2 | ...... | 1 | .3554 | 33.85 |
| 5 | ...do..... | 4,550 | .....do..................... | 5.06 | 7.35 | June 30 | 29 | 2 | .8939 | 36.95 |
| 6 | ...do..... | 4,550 | .....do..................... | 5.07 | 7.35 | June 28 | 29 | 2 | 1.3291 | 33.82 |
| 7 | Wheat.. | 4,550 | Clay loam.................. | 3.01 | 7.35 | June 22 | 23 | 2 | .9954 | 24.24 |
| 8 | ...do..... | 4,550 | .....do..................... | 4.17 | 7.35 | June 24 | 38 | 3 | 1.6230 | 25.77 |
| 9 | ...do..... | 4,550 | .....do..................... | 3.03 | 7.35 | June 6 | 58 | 4 | 2.3346 | 16.99 |
| 10 | Wheat.. | 4,550 | Clay loam.................. | 3.53 | 7.35 | May 10 | 109 | 5 | 2.3445 | 17.13 |
| 11 | ...do..... | 4,550 | .....do..................... | 6.06 | 7.35 | May 14 | 99 | 4 | 2.6808 | 18.72 |
| 12 | ...do..... | 4,550 | .....do..................... | 4.45 | 7.35 | May 10 | 105 | 5 | 3.2882 | 20.45 |
| | | | | | | | | | | *Tons.* |
| 13 | Alfalfa.. | 4,850 | Deep uniform clay loam.... | 7.52 | 7.35 | May 29 | 63 | 2 | 1.4190 | 3.83 |
| 14 | ...do..... | 4,850 | .....do..................... | 5.12 | 7.35 | May 7 | 107 | 3 | 2.4645 | 4.00 |
| 15 | ...do..... | 4,850 | .....do..................... | 6.60 | 7.35 | May 4 | 109 | 4 | 3.7354 | 3.68 |
| | | | | | | | | | | *Bushels.* |
| 16 | Wheat.. | 4,700 | Deep uniform clay loam... | 6.00 | 7.35 | June 30 | 39 | 3 | .7579 | 24.66 |
| 17 | ...do..... | 4,700 | .....do..................... | 5.16 | 7.35 | June 27 | 35 | 3 | 1.3089 | 23.83 |
| 18 | ...do..... | 4,700 | .....do..................... | 3.07 | 7.35 | June 25 | 43 | 3 | 2.2844 | 31.59 |
| 19 | Big "4" oats. | 4,700 | Deep uniform clay loam... | 4.73 | 7.35 | June 8 | 58 | 3 | .7833 | 41.22 |
| 20 | ...do..... | 4,700 | .....do..................... | 4.80 | 7.35 | June 6 | 47 | 3 | 1.2642 | 41.45 |
| 21 | ...do..... | 4,700 | .....do..................... | 4.90 | 7.35 | June 5 | 49 | 3 | 1.5722 | 41.22 |
| | | | | | | | | | | *Tons.* |
| 22 | Alfalfa.. | 4,300 | Deep clay loam............. | 3.82 | 7.35 | May 26 | 74 | 3 | 1.3327 | 3.94 |
| 23 | ...do..... | 4,300 | .....do..................... | 3.61 | 7.35 | May 7 | 95 | 4 | 2.3552 | 6.11 |
| 24 | ...do..... | 4,300 | .....do..................... | 5.77 | 7.35 | May 4 | 112 | 6 | 3.5394 | 6.10 |
| | | | | | | | | | | *Bushels.* |
| 25 | Wheat.. | 4,850 | Clay loam.................. | 4.96 | 7.35 | June 27 | 13 | 2 | .4737 | 12.29 |
| 26 | ...do..... | 4,850 | .....do..................... | 4.36 | 7.35 | June 24 | 17 | 2 | .8890 | 17.20 |
| 27 | ...do..... | 4,850 | .....do..................... | 4.83 | 7.35 | June 21 | 19 | 2 | .9253 | [1] 3.72 |
| 28 | Wheat.. | 4,300 | Medium clay loam.......... | 3.92 | 7.35 | June 7 | 25 | 2 | .6553 | 33.17 |
| 29 | ...do..... | 4,300 | .....do..................... | 4.19 | 7.35 | June 4 | 40 | 3 | 1.3949 | 35.32 |
| 30 | ...do..... | 4,300 | .....do..................... | 4.34 | 7.35 | June 5 | 69 | 3 | 2.1856 | 32.25 |
| 31 | Wheat.. | 4,300 | Medium clay loam.......... | 3.19 | 7.35 | June 28 | 17 | 2 | .7080 | 32.28 |
| 32 | ...do..... | 4,300 | .....do..................... | 3.18 | 7.35 | June 27 | 18 | 2 | 1.0016 | 51.57 |
| 33 | ...do..... | 4,300 | .....do..................... | 3.43 | 7.35 | June 26 | 18 | 2 | 1.2413 | 46.80 |
| 34 | Oats.... | 4,300 | Medium clay loam.......... | 4.11 | 7.35 | May 31 | 70 | 3 | .6514 | 34.42 |
| 35 | ...do..... | 4,300 | .....do..................... | 6.25 | 7.35 | May 11 | 97 | 4 | 1.2835 | 44.88 |
| 36 | ...do..... | 4,300 | .....do..................... | 2.27 | 7.35 | May 28 | 72 | 4 | 1.6017 | 49.33 |
| 37 | Wheat.. | 4,570 | Deep uniform clay loam.... | 7.05 | 7.86 | June 24 | ...... | 1 | .4930 | 39.7 |
| 38 | Oats.... | 4,570 | .....do..................... | 2.38 | 7.86 | June 25 | ...... | 1 | .7139 | 35.7 |
| | | | | | | | | | | *Tons.* |
| 39 | Sugar beets. | 4,570 | Uniform clay loam.......... | 7.83 | 7.86 | Aug. 8 | 17 | 2 | 1.6432 | 15.72 |
| | | | | | | | | | | *Bushels.* |
| 40 | Oats.... | 4,570 | Deep uniform clay loam.... | 4.35 | 7.86 | July 12 | 37 | 2 | 1.2930 | 33.3 |
| 41 | ...do..... | 4,570 | .....do..................... | 4.57 | 7.86 | July 16 | 34 | 2 | 1.7217 | 36.5 |
| 42 | ...do..... | 4,570 | .....do..................... | 3.91 | 7.86 | July 18 | 33 | 2 | 2.9109 | 16.6 |
| | | | | | | | | | | *Tons.* |
| 43 | Alfalfa.. | 4,700 | Deep........................ | 3.58 | 7.86 | May 26 | ...... | 1 | 1.0440 | 1.76 |
| 44 | ...do..... | 4,700 | .....do..................... | 2.69 | 7.86 | May 27 | ...... | 1 | 1.5148 | 2.6 |
| 45 | ...do..... | 4,700 | .....do..................... | 3.70 | 7.86 | May 28 | ...... | 1 | 1.8778 | 2.84 |

[1] Yield reduced by jack rabbits.

TABLE VIII.—*Effects of different volumes of water on grains, alfalfa, orchards, potatoes, and sugar beets during the season of 1913*—Continued.

| No. of plot. | Kind of crop. | Altitude. | Class of soil. | Area. | Precipitation April–September, inclusive. | Date of first irrigation. | Length of irrigation season. | Number of irrigations. | Total depth irrigation water applied. | Yield per acre. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Feet.* | | *Acres.* | *In.* | | *Days.* | | *Feet.* | *Tons.* |
| 46 | Alfalfa.. | 4,570 | Deep uniform clay loam.... | 3.12 | 7.86 | May 20 | 62 | 2 | 1.8571 | 3.9 |
| 47 | ...do..... | 4,570 | .....do.................... | 2.82 | 7.86 | May 18 | 63 | 2 | 1.7079 | 4.1 |
| 48 | ...do..... | 4,570 | .....do.................... | 4.05 | 7.86 | May 22 | 85 | 3 | 1.9375 | 3.89 |
| | | | | | | | | | | *Boxes.* |
| 49 | Orchard | 3,825 | Medium clay loam.......... | 4.58 | 7.58 | July 17 | 45 | 3 | .3394 | 300 |
| | | | | | | | | | | *Pounds.* |
| 50 | Wheat.. | 3,572 | Uniform clay loam......... | .190 | 2.39 | .......... | ...... | 0 | .00 | 0.00 |
| 51 | ...do..... | 3,572 | .....do.................... | .0873 | 2.39 | June 3 | ...... | 1 | .2989 | 1,030.93 |
| 52 | ...do..... | 3,572 | .....do.................... | .0956 | 2.39 | ...do..... | 35 | 2 | .5147 | 1,558.58 |
| 53 | ...do..... | 3,572 | .....do.................... | .0987 | 2.39 | June 4 | 34 | 3 | .5412 | 1,661.60 |
| 54 | ...do..... | 3,572 | .....do.................... | .0851 | 2.39 | ...do..... | 48 | 4 | .9776 | 1,703.88 |
| 55 | ...do..... | 3,572 | .....do.................... | .0838 | 2.39 | ...do..... | 48 | 5 | 1.1816 | 1,551.31 |
| 56 | ...do..... | 3,572 | .....do.................... | .0945 | 2.39 | June 5 | 53 | 9 | 1.8633 | 2,571.43 |
| 57 | Wheat.. | 3,572 | Uniform clay loam......... | .1925 | 2.39 | .......... | ...... | 0 | .00 | 0.00 |
| 58 | ...do..... | 3,572 | .....do.................... | .0987 | 2.39 | June 3 | ...... | 1 | .2644 | 1,109.42 |
| 59 | ...do..... | 3,572 | .....do.................... | .1033 | 2.39 | June 4 | 34 | 2 | .4749 | 1,839.30 |
| 60 | Wheat.. | 3,572 | Uniform clay loam......... | .0838 | 2.39 | ...do..... | 34 | 3 | .6913 | 2,273.27 |
| 62 | ...do..... | 3,572 | .....do.................... | .0894 | 2,39 | ...do..... | 48 | 4 | 1.1846 | 1,879.19 |
| 63 | ...do..... | 3,572 | .....do.................... | .0945 | 2.39 | ...do..... | 48 | 5 | 1.2551 | 1,888.89 |
| 64 | ...do..... | 3,572 | .....do.................... | .1024 | 2.39 | June 5 | 53 | 9 | 2.1977 | 3,632.81 |
| 65 | Wheat.. | 3,572 | Uniform clay loam......... | .1949 | 2.39 | .......... | ...... | 0 | .00 | 0.00 |
| 66 | ...do..... | 3,572 | .....do.................... | .0851 | 2.39 | June 3 | ...... | 1 | .2576 | 1,339.60 |
| 67 | ...do..... | 3,572 | .....do.................... | .0801 | 2.39 | June 4 | 34 | 2 | .4997 | 1,922.60 |
| 68 | ...do..... | 3,572 | .....do.................... | .0987 | 2.39 | ...do..... | 34 | 3 | .6903 | 1,377.91 |
| 69 | ...do..... | 3,572 | .....do.................... | .0999 | 2.39 | ...do..... | 48 | 4 | .9300 | 1,321.32 |
| 70 | ...do..... | 3,572 | .....do.................... | .0869 | 2.39 | ...do..... | 48 | 5 | 1.0969 | 2,531.65 |
| 71 | ...do..... | 3,572 | .....do.................... | .0765 | 2.39 | June 5 | 53 | 9 | 1.8359 | 3,542.48 |
| 72 | Barley.. | 3,572 | Uniform clay loam......... | .6541 | 2.39 | May 31 | ...... | 1 | .3902 | 2,057.79 |
| 73 | ...do..... | 3,572 | .....do.................... | .6938 | 2.39 | May 30 | 24 | 2 | .8168 | 1,948.69 |
| 74 | ...do.... | 3,572 | .....do.................... | .6019 | 2.39 | ...do..... | 36 | 3 | 1.4302 | 2,267.82 |
| 75 | Barley.. | 3,572 | Uniform clay loam......... | 1.4073 | 2.39 | May 1 | 49 | 2 | 1.3714 | 1,227.17 |
| 76 | ...do..... | 3,572 | .....do.................... | .7466 | 2.39 | Apr. 30 | 90 | 3 | 2.6734 | 1,222.88 |
| 77 | ...do..... | 3,572 | .....do.................... | .7400 | 2.39 | Apr. 29 | 90 | 5 | 2.7490 | 1,572.97 |
| 78 | Oats.... | 3,572 | Uniform clay loam......... | .9526 | 2.39 | May 6 | 34 | 2 | 1.2858 | 1,709.10 |
| 79 | ...do..... | 3,572 | .....do.................... | .4943 | 2.39 | May 7 | 80 | 3 | 1.6123 | 1,723.65 |
| 80 | ...do..... | 3,572 | .....do.................... | .4943 | 2.39 | May 8 | 81 | 5 | 2.7353 | 2,120.17 |
| 81 | Potatoes | 3,572 | Uniform clay loam......... | .644 | 2.39 | July 12 | ...... | 1 | .793 | 12,251.55 |
| 82 | ...do..... | 3,572 | .....do.................... | .644 | 2.39 | July 11 | 32 | 3 | 1.250 | 18,416.15 |
| 83 | ...do..... | 3,572 | .....do.................... | .618 | 2.39 | July 10 | 49 | 6 | 3.127 | 22,095.47 |
| 84 | Alfalfa.. | 3,572 | Uniform clay loam......... | .4325 | 2.39 | May 22 | 86 | 3 | 1.1763 | 10,601.16 |
| 85 | ...do..... | 3,572 | .....do.................... | .5271 | 2.39 | May 21 | 87 | 4 | 1.8194 | 9,685.07 |
| 86 | ...do..... | 3,572 | .....do.................... | .4731 | 2.39 | May 10 | 97 | 5 | 1.8468 | 10,410.06 |
| 87 | ...do..... | 3,572 | .....do.................... | .5032 | 2.39 | May 9 | 98 | 7 | 1.9811 | 11,705.09 |
| 88 | ...do..... | 3,572 | .....do.................... | .4798 | 2.39 | ...do..... | 109 | 10 | 3.0548 | 13,989.16 |
| 89 | ...do..... | 3,572 | .....do.................... | .5372 | 2.39 | May 8 | 118 | 13 | 3.3388 | 15,022.34 |

**VARIATIONS IN IRRIGATION REQUIREMENTS OF SOILS.**

A study of the results secured indicates that the porosity of the soil is one of the most important factors influencing the irrigation requirements of soils, and for the purpose of comparison the soils have been divided into two classes, according to their physical charac-

teristics: (1) The heavier soils, consisting of the clay, clay loams, sandy loam, and fine sandy soils; and (2) the porous soils, consisting of the coarse sandy and gravelly soils. The difference in the requirements of these two classes is illustrated by Table IX.

TABLE IX.—*Average volumes of water used on tracts with different types of soil.*

| No. | Description. | Acre-feet used. | | |
|---|---|---|---|---|
| | | All soils. | Impervious soils. | Porous soils. |
| 1 | All tracts included in the investigation | [1]2.06 | [1]1.60 | 4.66 |
| 2 | All alfalfa tracts included in the investigation | 3.35 | 2.40 | 7.10 |
| 3 | All grain tracts included in the investigation | 1.56 | 1.32 | 3.19 |

[1] Average low, due to fact that 74 per cent of tracts included was grain.

## VARIATIONS IN IRRIGATION REQUIREMENTS OF CROPS.

Table X is made up from the data secured on the medium clay loam type of soils and shows, by crops, the average quantities applied to the majority of the tracts of this type included in the investigation.

TABLE X.—*Average volumes of water applied to different crops on medium or clay loam soils.*

| No. | Kind of crop. | Number of plots. | Average volume of water applied per acre. |
|---|---|---|---|
| | | | *Acre-feet.* |
| 1 | Winter grain | 15 | 0.82 |
| 2 | Spring grain | 216 | 1.27 |
| 3 | Alfalfa | 79 | 2.43 |
| 4 | Pasture | 13 | [1]3.02 |
| 5 | Potatoes | 17 | 1.71 |
| 6 | Orchard | 11 | 1.45 |

[1] Waste not deducted from volume applied to part of tracts included. Proper average quantity retained approximately 2.8 acre-feet.

Table X shows that different crops received different volumes of water and that for the purpose of comparison they may be safely divided into two classes—the winter and spring grains, potatoes, and orchards falling in one class and the alfalfa and pasture falling in the other. The table does not show the irrigation requirement for the various crops on this type of soil, for some of the experiments showed rather low yields, due to excessive or insufficient water.

In order to throw light upon the irrigation requirements of the two classes into which the crops observed may have been divided, the data have been combined in a different manner in Table XI. In this table the yields from the plots making the maximum yields from all experiments on clay loam soils, irrespective of the quantity of water applied, are compared with the average quantities applied and yields produced from all plots on the same type of soil.

TABLE XI.—*Comparison of volumes of water used on plots giving maximum yields and the average volumes used on all plots on clay loam soils during 4 years, 1910 to 1913, inclusive.*

| Description of plots. | Number of plots. | Average volume of water applied per acre. | Average yield per acre. | Average yield per acre-foot of water. |
|---|---|---|---|---|
| Alfalfa: | | *Acre-feet.* | | |
| All plots included in investigation | 79 | 2.40 | 4.91 tons | 2.04 tons. |
| Plots making maximum yield in each experiment. | 26 | 2.73 | 5.47 tons | 2 tons. |
| Grain and cultivated crops: | | | | |
| All plots included in investigation | 221 | 1.33 | 36.38 bushels | 27.39 bushels. |
| Plots making maximum yield in each experiment. | 60 | 1.74 | 44.92 bushels | 25.79 bushels. |

Table XI shows that the average quantity required to produce the maximum yield of crops was greater than the average quantity applied to all tracts included in the investigation. All the results from the experiments on clay loam soils have been plotted as curves, the volume of water applied and the yield produced being the two factors considered.

Figure 3 shows both the individual and the average yields secured, and the quantities of water applied to some 207 fields of spring and winter grains. The yields upon soils that have been fertilized either with manure or by the plowing under of alfalfa sod have been plotted as triangles, while those upon ordinary or infertile soils have been plotted as small circles. The points representing both fertile and infertile soils are widely scattered, indicating that the results secured from any one plot can not be depended upon and that only an average of the results from a large number of experiments should be taken into consideration. The points representing each experiment have been connected by straight lines. The curves showing the average of results in both fertile and infertile soils have been constructed by averaging the points at which these lines crossed the vertical lines of the diagram. Owing to the many factors which may affect the size of the crop produced with any given quantity of water, as is indicated by the variation in the points upon which the curves are based, these curves will not definitely fix the size of the crop that can be produced on any particular tract. Each is based upon a large number of determinations, however, and shows within reasonable limits the results which may be expected from clay loam soils.

A comparison of the two curves shows that a much higher efficiency is almost invariably secured from the water when applied to fertile soil, and they both show that with either the yields may be expected to increase as the water applied is increased until as much as 1½ feet per acre have been applied, after which the yields will tend to decrease with greater applications. These curves show a striking agreement with the results given in Table XI and would

seem to prove that on an average about 1½ feet of water per acre are required for the maximum yield of grain on the average soil of Idaho.

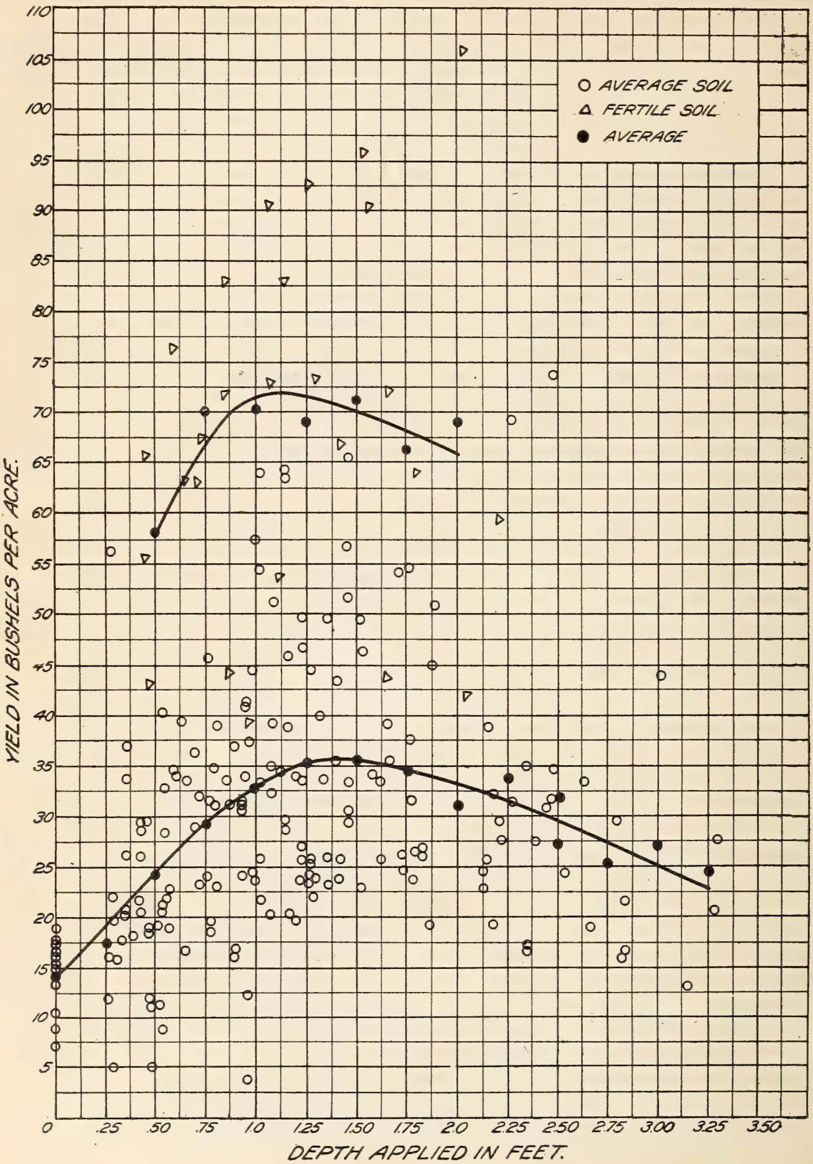



FIG. 3.—Irrigation requirement curve based on yields and amounts of water applied to 207 individual fields of grain on clay loam soils in Idaho during the seasons 1910 to 1913, inclusive.

The curve shown in figure 4 is made up from the results secured on 77 fields of alfalfa and clover on clay loam soil and shows marked tendency toward increase in yield as the application of water is in-

creased, as there is no appreciable break in the curve within the limit of the experiments. This curve shows again that alfalfa and clover require much larger supplies of water than grain, but the increase in the yield of alfalfa is not proportional to the increase in the water applied. Notwithstanding the fact shown by the curve, that the yield continues to increase with increased quantities of water, other considerations, such as the danger of water-logging land and the

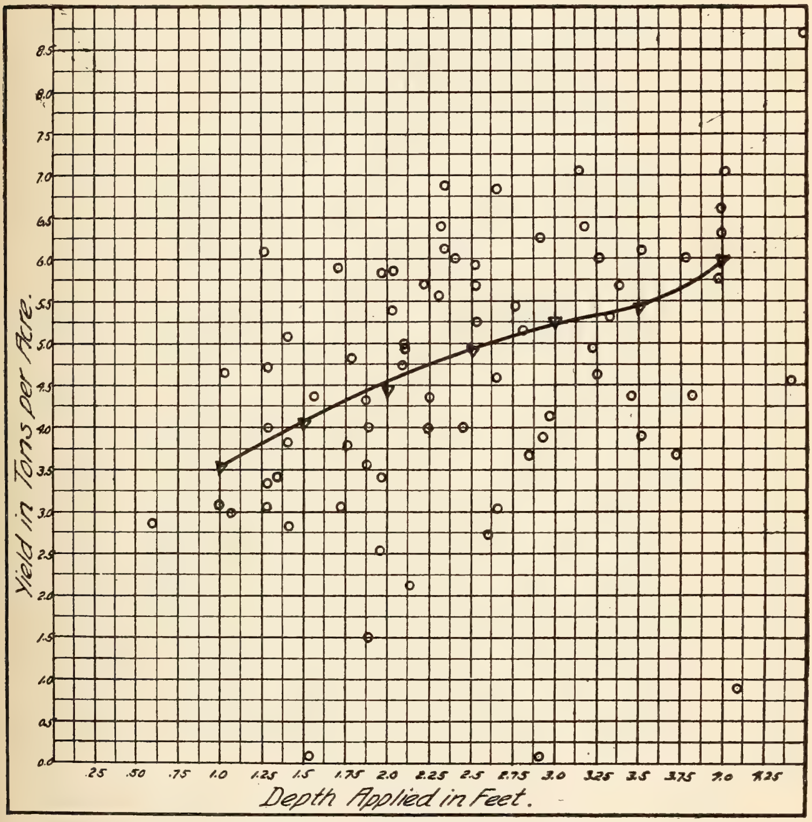



FIG. 4.—Curve based on yields and amount of water applied to 77 individual fields of alfalfa on clay loam soils in Idaho, during 5 seasons, 1910 to 1914.

limitation of the acreage which can be irrigated with a given water supply, would make it appear somewhat doubtful whether more than 3 feet per acre should ever be allotted to alfalfa on medium clay loam soil.

The alfalfa curve (fig. 4) was made up from observed data by first plotting all points on the sheet, after which points representing different plots of each experiment were connected up by straight lines similar to the method used with the grain curve (fig. 3). The depths

represented by the point where the various lines crossed each 0.5 foot in depth were then averaged, thus fixing the curve.

TABLE XII.—*Averages upon which alfalfa curve is based.*

| Depth. | Number of points considered. | Average yield. | Depth. | Number of points considered. | Average yield. |
|---|---|---|---|---|---|
| *Feet.* | | | *Feet.* | | |
| 1.0 | 4 | 3.57 | 3.0 | 13 | 5.30 |
| 1.5 | 11 | 4.10 | 3.5 | 10 | 5.38 |
| 2.0 | 16 | 4.40 | 4.0 | 5 | 6.06 |
| 2.5 | 16 | 4.86 | 4.5 | 3 | 6.96 |

The curves in figures 3 and 4 show the average yields which were produced on the average clay loam soils of southern Idaho with given volumes of water, there having been a wide divergence in the results upon which they are based, and it should not be inferred that they will check exactly with the results from any individual farm.

The effect of fertility on the return of grain from the use of given quantities of water is illustrated further by an experiment which was carried on at the Twin Falls experiment station during the season of 1914. Six adjoining one-tenth-acre plots of rather infertile soil were planted to Marquis wheat. The land devoted to these plots had been farmed to grain six years after the sagebrush had been removed. Three of the plots were fertilized moderately, with applications at the rate of 15 loads of barnyard manure per acre; the remaining three were left in their original condition and did not receive any fertilizer. Two of the plots, one fertilized and one unfertilized, received an application of 1 foot of water per acre; the second two plots, one being unfertilized, received an average application of 2 feet per acre; and the third set of two plots, one of which was unfertilized, received an application of approximately 3 feet per acre. The results secured are shown in Table XIII.

TABLE XIII.—*Effect of fertilizer upon yield and irrigation requirements.*

| No. | Method of treatment. | Area. | Number of irrigations. | Water applied per acre. | Yield of grain per acre. | Yield of grain per acre-foot of water applied. |
|---|---|---|---|---|---|---|
| | | *Acres.* | | *Feet.* | *Pounds.* | *Pounds.* |
| 1 | Unfertilized | 0.094 | 3 | 1.05 | 1,000 | 952 |
| 2 | ....do | .094 | 5 | 1.94 | 1,144 | 590 |
| 3 | ....do | .094 | 7 | 2.99 | 1,266 | 423 |
| 4 | Fertilized | .092 | 3 | 1.07 | 1,467 | 1,371 |
| 5 | ....do | .092 | 5 | 2.01 | 1,663 | 827 |
| 6 | ....do | .092 | 7 | 3.05 | 1,826 | 599 |

Results during the same season upon fertile alfalfa-sod ground 30 miles north of Twin Falls, at the Gooding experiment station, indi-

cated that the maximum yields were made with approximately 1 foot of water per acre, and that applications in addition to this quantity made a considerable decrease in the yield. There is no doubt that had the fertilized plots of the Gooding experiment been more fertile the largest yield would have been made with the 1 foot per acre.

This Gooding experiment, together with the other experiments which have been made, seems to prove conclusively that less water is required for the production of a given yield of crop on fertile soils than is required for the same yield of crop on infertile soils and emphasizes the necessity of maintaining a high state of fertility in cases where a high duty of water must be secured. It does not mean, however, that less water is required by the fertile soils, for, as shown by figure 3, fully as much is required for maximum crop production, a greatly increased yield being produced on the fertile soils.

### RESULTS SECURED WITH INDIVIDUAL CROPS.

In order to show the results secured from single crops on the same type of soil, curves are shown in figures 5, 7, and 8. Each of these curves is based upon five years' results at the Gooding experiment station. The average amount of precipitation during the growing season for four of these five years was 2.92 inches. Considering that each of these curves is based upon a number of experiments, that this station lies at the average altitude for southern Idaho, and that the soil, which is a medium clay loam, rather impervious, and averaging 6 to 8 feet in depth, is representative, it is believed that the results plotted are typical of what may be expected throughout the State, and that they show within a reasonable limit the yield of crop which may be produced with a given quantity of water. These curves do not necessarily indicate a proper duty of water under good practice in Idaho, since, as is later stated, local economic features enter largely into all such problems.

The curves in figure 5 show the average results secured from 96 plots of staple varieties of spring wheat grown during the five seasons. One curve shows yields per acre, and the other yields per acre-foot of water applied. Considering the large number of plots upon which these curves are based, they should be very dependable. The curve showing yield per acre agrees with the data secured elsewhere throughout the State, in that it shows that the yield of grain will normally increase as the water applied is increased until an amount varying between 1.4 and 1.8 acre-feet per acre has been applied, after which the application of more water will decrease the yield of grain and in many cases the yield of straw as well (fig. 6). The curve showing yields per acre-foot of water (fig. 5) shows that the highest efficiency from water applied to spring grains is secured where the smaller quantities are

used. Where 2.8 feet per acre were applied each acre-foot gave a return of 584 pounds of grain, while an application of but 0.4 foot per acre yielded at the rate of 3,474 pounds per acre-foot, or very nearly six times as much grain per unit of water as was secured where the larger application was made. It must be noted, however, that the yield per acre with the application of but 0.4 foot per acre was rather

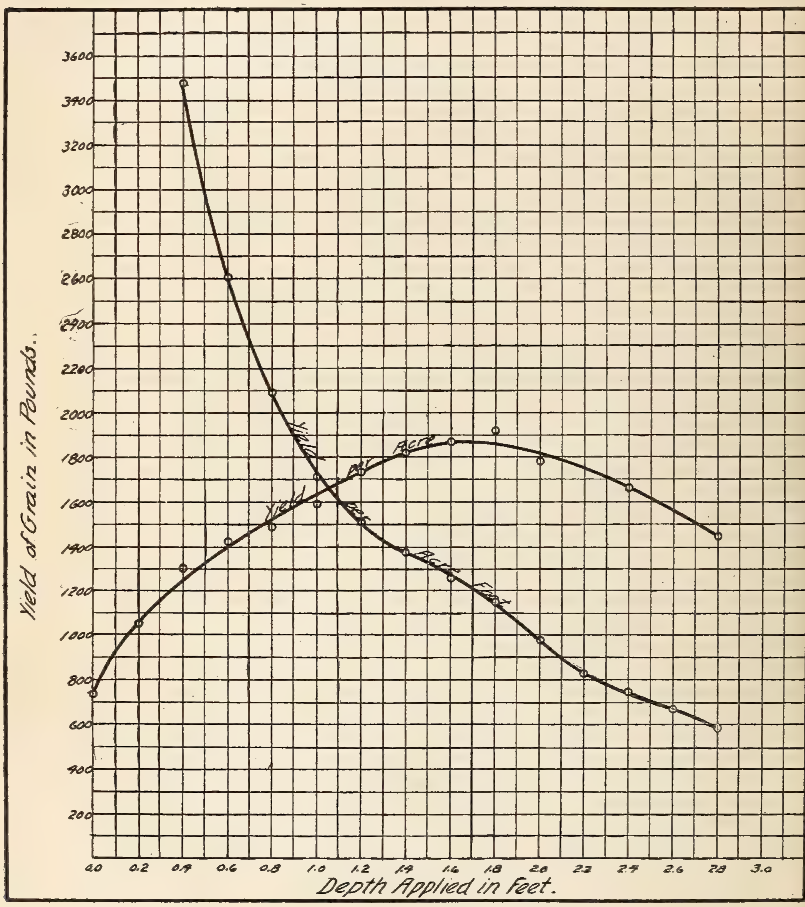



FIG. 5.—Yield per acre and per acre-foot of water applied from 96 plots of spring wheat at Gooding experiment station during five years, 1910 to 1914.

low and would not be profitable in many cases, because the returns would not equal the cost of production. While these two curves indicate the results which will be obtained by applying different volumes of water to spring wheat on this type of soil for the conditions obtained in southern Idaho, the economic quantity to allot for grain is a distinct problem. Whether it is more profitable to use little water per acre and get a large return per acre-foot of water and a low yield from the land, or to use more water and get a large return

per acre from the land and a low return per acre-foot of water depends on the relative cost of land and water, the cost of production, and other factors. The solution of the problem in each instance depends on local economic conditions.

The curves presented in figure 7 show the average results secured from 21 plots of alfalfa grown during five years at the Gooding experiment station, and also of three plots grown at Buhl, 30 miles away, on the same type of soil. These curves show that alfalfa requires large quantities of water and that the yield increases as the

FIG. 6.—Effect of different amounts of water on the yield of straw, Gooding experiment station.

supply of water is increased, sufficient water not having been applied to determine at what point the excessive supply begins to decrease the yield of alfalfa. The lower curve shows yields of hay per acre-foot of water applied and indicates that while less efficiency is secured from water where large applications are made, the decrease is not nearly so pronounced as when they are applied to grain. These curves and the data from which they were constructed are typical of the results secured throughout other districts of Idaho on this same type of soil and show that if yield alone is considered it is difficult to apply too much water to alfalfa, provided no more is applied at one time than will be promptly absorbed by the soil. The proper quantity to allow for alfalfa, however, as with the grains, will be determined by local economic conditions.

The curves shown in figure 8 are made up from the results secured from 16 plots of potatoes grown at the Gooding experiment station during five years. The curves show that potatoes require somewhat more water than the grains and that there was a strong tendency for the yield to increase as the supply of water was increased within the limits of the experiment. Since the rate of increase in yield grows smaller as the quantity of water is increased, it probably will not be advisable or profitable to apply more than 2 or 2½ feet per acre to

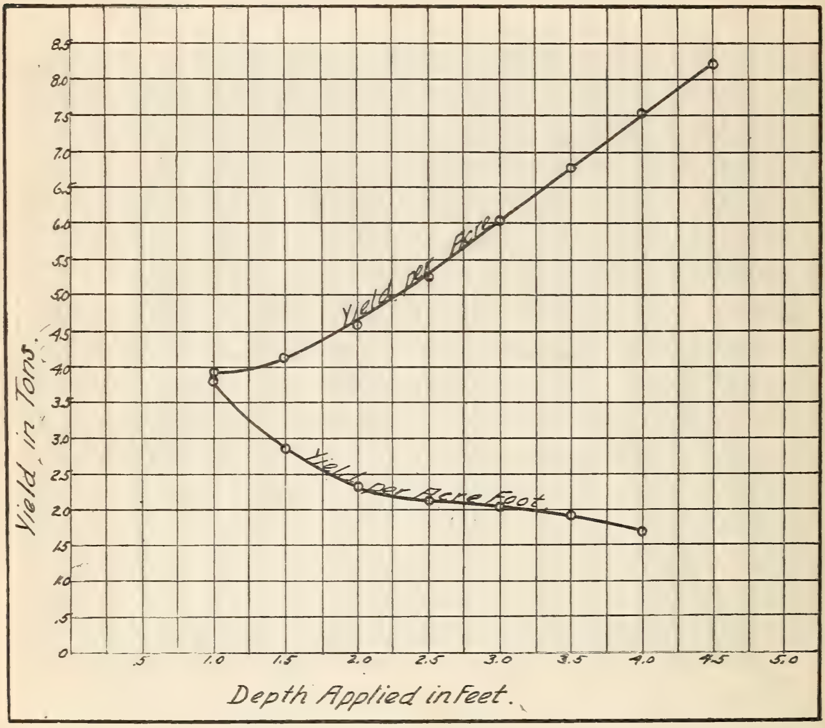



FIG. 7.—Yield per acre and per acre-foot of water applied from 24 plots of alfalfa at Buhl and Gooding during 5 years, 1910–1914.

potatoes on clay loam soil under conditions similar to those existing in the vicinity of Gooding. Here, as before, the curves indicate within reasonable limits the results which may be obtained with different volumes of water, and the quantity to apply in each case will be determined by local economic conditions.

IRRIGATION REQUIREMENTS AT DIFFERENT TIMES DURING THE SEASON.

The curves (figs. 5 and 7) do not show the proportion of the season's supply required at different times. In the design of irrigation projects, whether they be dependent upon reservoirs or direct diversion from

a stream, or whether water be pumped, it is necessary to know this factor. The irrigation requirements at different times throughout the season are controlled by the crops grown and the climate of the locality in question. Alfalfa or pasture in any arid region usually requires water throughout the growing season, or from early spring until late fall, while the grains require water during not to exceed the first one-half or two-thirds of the season. Potatoes require water throughout the season, but do not need it so early as grains.

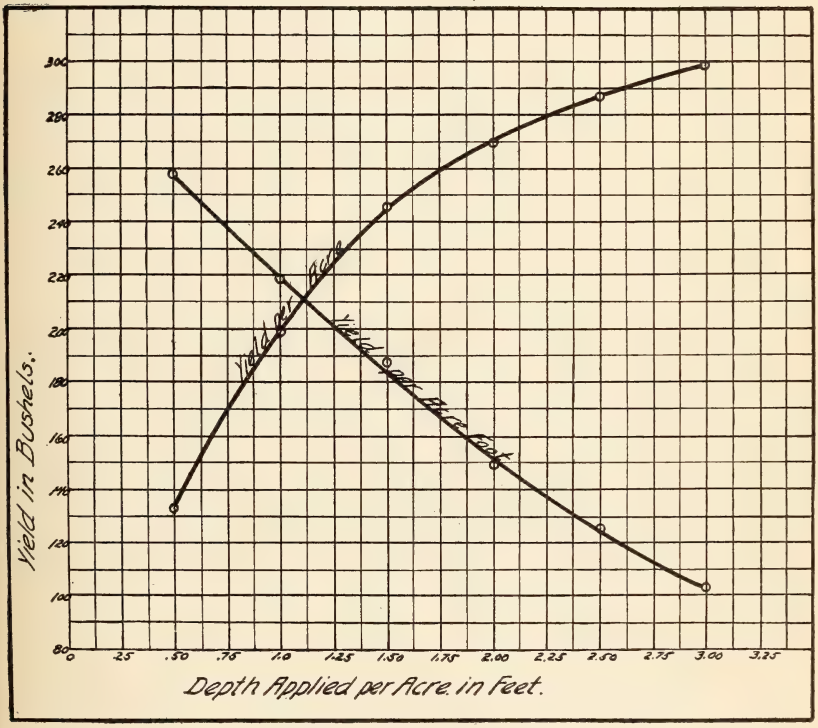



FIG. 8.—Yield yer acre and per acre-foot of water applied from 16 plots of potatoes at Gooding experiment station during 5 years, 1910 to 1914.

Beets and orchards when well cultivated need little water in the early part of the season, the greater part of their requirements occurring from July to September, inclusive.

For the purpose of throwing more light upon the total requirements during the season and showing the proportion of the whole required during each month, the data secured from both the medium and porous soils have been reclassified in the following manner: (1) The data for each class of crop on each class of soil (for classes, see p. 20) have been segregated; (2) the average depths of water applied to the tracts for each month and for the season have been computed; and (3) tracts on which the yield was appreciably reduced by

deficient or excessive water application have been eliminated, as have a few tracts on which a very large increase in water application was necessary to produce a small increase in the yield. The remaining data, some 50 per cent of the original data secured, have been grouped in Tables XIV and XV.

TABLE XIV.—*Average depths of water applied to 119 selected fields of grain and potatoes on medium clay and sandy loam soils, by months.*

[Altitudes ranging from 2,400 to 5,000 feet.]

| Season. | Number of plots. | Depth of water applied. | | | | | |
|---|---|---|---|---|---|---|---|
| | | Apr. 16–30. | May. | June. | July. | August. | Total for season. |
| | | *Foot.* | *Foot.* | *Foot.* | *Foot.* | *Foot.* | *Feet.* |
| 1910 | 31 | ........ | 0.32 | 0.60 | 0.55 | 0.08 | 1.55 |
| 1911 | 30 | ........ | .03 | .65 | .48 | .01 | 1.17 |
| 1912 | 25 | ........ | ........ | .94 | .66 | .05 | 1.65 |
| 1913 | 33 | 0.04 | .21 | .54 | .59 | .23 | 1.61 |
| Average | ........ | .01 | .14 | .68 | .57 | .09 | 1.50 |
| Per cent of total | ........ | .67 | 9.28 | 45.91 | 38.10 | 6.06 | ........ |

Table XIV shows that both the months and the seasons have varied somewhat in their requirements and that the average annual requirement of water for this class of crop was 1.50 feet per acre. The results shown by the table are based upon the same data as are included in figures 5, 7, and 8, but were arrived at in a different manner. There is a very close agreement in that the requirement of water shown by the table is practically the same amount as that which the curves indicate will produce the maximum yield on both fertile and infertile soils.

Table XV shows the average depths of water used on alfalfa, arrived at in the same way.

TABLE XV.—*Average depths of water applied to 52 selected fields of alfalfa and clover on medium clay and sandy loam soils.*

[Altitudes ranging from 2,400 to 5,000 feet.]

| Season. | Number of plots. | Depth of water applied. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | April— | | May. | June. | July. | August. | September. | Total for season. |
| | | 1–15. | 16–30. | | | | | | |
| | | *Foot.* | *Foot.* | *Foot.* | *Foot.* | *Foot.* | *Foot.* | *Foot.* | *Feet.* |
| 1910 | 15 | 0.06 | 0.02 | 0.55 | 0.74 | 0.65 | 0.61 | 0.07 | 2.70 |
| 1911 | 13 | ........ | .04 | .49 | .29 | .91 | .70 | .25 | 2.68 |
| 1912 | 11 | ........ | ........ | .49 | .50 | .62 | .61 | .04 | 2.26 |
| 1913 | 13 | ........ | ........ | .86 | .23 | .74 | .39 | .02 | 2.24 |
| Average | ........ | .02 | .02 | .60 | .44 | .73 | .58 | .10 | 2.49 |
| Per cent of total | ........ | .8 | .8 | 24.1 | 17.7 | 29.3 | 23.3 | 4.0 | ........ |

The average annual requirement of 2.49 feet of water per acre is less than the amount required to produce maximum yields, as shown by figures 4 and 7, where an application of 2½ feet produced yields of 5.25 and 4.86 tons per acre, respectively, with an increasing yield as the quantity applied was increased. The curves, however, do not show at what point economy demands that the quantity applied be fixed, and it is believed that the table does show this for economic conditions similar to those in Idaho.

The United States census of 1910 showed average yields of irrigated alfalfa as follows: Idaho, 3.27 tons per acre; Oregon, 3.29; Washington, 3.98; and California, 3.49, all other States having a less average yield. Considering these average yields along with the facts shown by both the table and the curves, and also the danger of water-logging the land and the curtailment of the State's irrigated area, it is believed that 2.5 feet of water per acre represents the proper allotment for alfalfa on clay loam soil under economic conditions similar to those of Idaho.

Each of Tables XIV and XV shows the monthly and seasonal requirements of only one class of crops. Hence, before the data contained in either or both of them may be used for the determination of the proper allotment on an entire project, it becomes necessary to know what crops will be grown upon the project, for alfalfa and pasture require so much more water than grains that the ultimate acreage of each particular class of crops becomes a dominant factor. In order to throw light upon this subject and furnish an accurate basis for combining the two tables to show the requirements of an entire project, a census of several typical Idaho irrigation projects was secured, the results being shown in Table XVI.

TABLE XVI.—*Areas devoted to different crops.*

| District. | Year. | Hay and pasture. | | Grain, potatoes, and orchard. | | Total. |
|---|---|---|---|---|---|---|
| | | Area. | Per cent of total. | Area. | Per cent of total. | |
| | | *Acres.* | | *Acres.* | | *Acres.* |
| Twin Falls South Side project | 1912 | 70,043 | 47.55 | 77,266 | 52.45 | 147,309 |
| Do | 1913 | 67,115 | 44.95 | 82,196 | 55.05 | 149,311 |
| Seven Boise Valley projects | 1911 | [1] 26,253 | [1] 59.75 | 17,684 | 40.25 | 43,937 |
| Six Boise Valley projects | 1912 | 24,492 | 57.90 | 17,804 | 42.10 | 42,296 |
| Total | | 187,902 | | 194,950 | | 382,853 |
| Average | | | 49.08 | | 50.92 | |

[1] This area and percentage was somewhat above normal on account of the comparatively large acreage of bottom land that was seeded to pasture under some of those canals.

Table XVI shows that under normal Idaho conditions almost exactly one-half of the irrigated acreage is devoted to each class into which the crops of the investigation have been divided. (See also p.

53.) As these were comparatively old, well-developed projects, and normal in every way, there is good reason to believe that the acreages of the different crops on other projects will bear practically the same relationship to one another in the future. If this is the case, and the normal project of the West is ultimately devoted to approximately equal acreages of (1) spring and winter grains, root crops, and orchards, and (2) alfalfa, clover, pastures, and crops requiring similar quantities of water, the requirements of the projects as a whole will be found by averaging the requirements of the two classes of crops. This has been done in Table XVII, each line of the table representing the requirement of one class during a single year of the investigation. The average given in the table therefore shows the combined requirements during each month of the irrigation season for the two classes of crops during the four years of the investigation, the process of averaging having neutralized and offset the eccentricities of irrigators and the individual differences of the seasons, stand of crop, soils, and plots included in the investigation.

TABLE XVII.—*Average depths of water applied to 171 selected fields of grain and alfalfa on medium clay and sandy loam soils.*

[Altitudes ranging from 2,400 to 5,000 feet.]

| Crop. | Season. | Number of plots. | Depth of water applied. | | | | | | | | Total for season. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | April— | | May. | June. | July. | August. | September— | | |
| | | | 1–15 | 16–30 | | | | | 1–15 | 16–30 | |
| | | | *Foot.* | *Foot.* | *Foot.* | *Foot.* | *Foot.* | *Foot.* | *Foot.* | *Feet.* | *Feet.* |
| Alfalfa | 1910 | 15 | 0.06 | 0.02 | 0.55 | 0.74 | 0.65 | 0.61 | 0.07 | ...... | 2.70 |
| Grain | 1910 | 31 | ...... | ...... | .32 | .60 | .55 | .08 | ...... | ...... | 1.55 |
| Alfalfa | 1911 | 13 | ...... | .04 | .49 | .29 | .91 | .70 | .25 | ...... | 2.68 |
| Grain | 1911 | 30 | ...... | ...... | .03 | .65 | .48 | .01 | ...... | ...... | 1.17 |
| Alfalfa | 1912 | 11 | ...... | ...... | .49 | .50 | .62 | .61 | .04 | ...... | 2.26 |
| Grain | 1912 | 25 | ...... | ...... | ...... | .94 | .66 | .05 | ...... | ...... | 1.65 |
| Alfalfa | 1913 | 13 | ...... | ...... | .86 | .23 | .74 | .39 | .02 | ...... | 2.24 |
| Grain | 1913 | 33 | ...... | .04 | .21 | .54 | .59 | .23 | ...... | ...... | 1.61 |
| Average | ...... | ...... | .01 | .01 | .37 | .56 | .65 | .34 | .04 | ...... | 1.98 |
| Per cent of total | ...... | ...... | .5 | .5 | 18.7 | 28.3 | 32.8 | 17.2 | 2.0 | ...... | ...... |

Table XVII is a general average of the results which have been secured on the average soil of southern Idaho during the entire four years' investigation, after eliminating the results secured from all tracts whose yield was reduced by excessive or insufficient application, and is considered by far the most important table included in this report. The facts given in the table are shown graphically in figure 9. It is in reality the meat, or final result, of the entire four years' study of water investigation, and as the soil in question is an average of that which is, or will be, included in at least 75 per cent of Idaho's irrigation projects, and probably of as large a per cent of the projects in many other States, it is believed

that this table may be used far more than the corresponding one (Table XVIII), which shows the average volumes of water applied to porous soils. As has been stated elsewhere in this report, the irrigation requirements of any particular crop on any soil are influenced by many factors and will be found to vary on different farms and during different years, but as this table includes the results of 171 selected tracts of this particular type of soil, covering a period of four years, thus effectually neutralizing the individual differences of

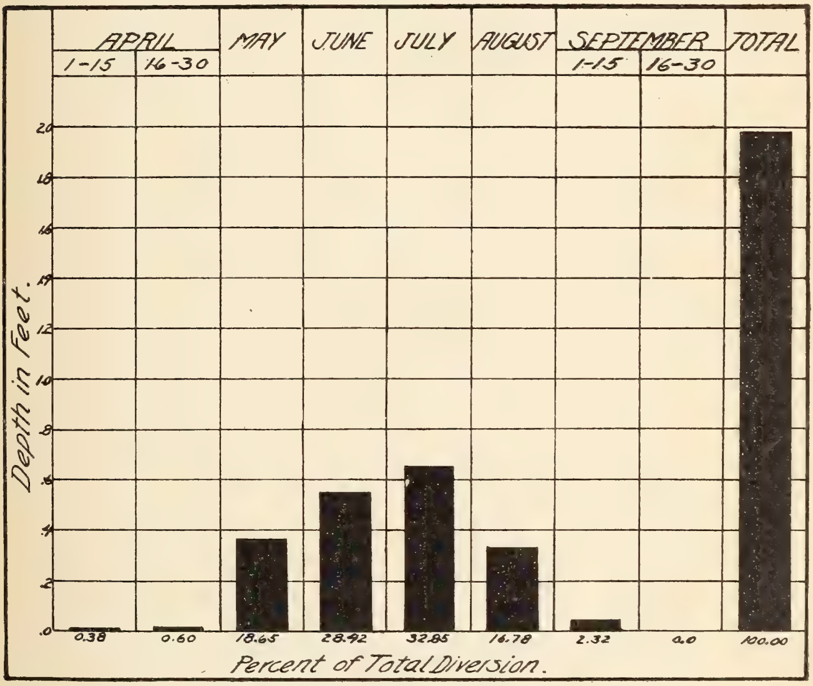



FIG. 9.—Amounts of water required each month of the irrigation season by an Idaho project devoted to equal areas of grain and hay on medium clay loam or sandy loam soil.

the seasons, of irrigators, and of the tracts themselves, it is considered that the results will be found to be very dependable

Keeping in mind that the table shows averages only, and that individual crops, farms, projects, and seasons are bound to depart from the average, the table shows that a project devoted to equal areas of (1) grain, orchards, and general root crops, and (2) hay, including alfalfa, clover, timothy, and pasture, on average southern Idaho soil should furnish sufficient water so that an average of 2 feet can be retained on each and every irrigated acre during the season. Of this quantity, which is exclusive of the precipitation, 0.01 foot in depth, or 0.5 per cent, will be required during the first half of April;

0.01 foot in depth, or 0.5 per cent, will be required in the last half of April; 0.37 foot in depth, or 18.7 per cent, during May; 0.56 foot in depth, or 28.3 per cent, during June; 0.65 foot in depth, or 32.8 per cent, during July; 0.34 foot in depth, or 17.2 per cent, during August; and 0.04 foot in depth, or 2 per cent during the first half of September, making a total of 1.98 acre-feet.

The above estimates are based strictly upon the crop needs, as shown by the irrigation-requirement investigation, and include nothing for stock water or that which may be required for domestic purposes, nor is there any included for waste from the fields or for late fall or winter irrigation. If the data in this table are to be used in allotting water to an irrigation project, and if the water is to be used for the above-mentioned purposes, these factors must be taken into consideration.

Table XVIII shows that there is small need for water earlier than May or later than August and that with all of the tracts considered there has been no need for water during the four years of the investigation by either alfalfa or grain during the last half of September. It shows also that over 60 per cent of the total water required during the season is required in the 61-day period covering June and July. The table will be found useful to those called upon to design storage projects, as a variety of curves can be worked up from it, which, taken in connection with the hydrograph of the discharge of the stream from which the supply is to be derived, will show how much of the water it will be necessary to store.

It also will be helpful in the designing of pumping plants, and particularly in determining the size of the various pumping units that should be installed. The table shows that any large pumping plant should consist of more than one unit, and possibly as many as three or four, for a unit that could economically supply the maximum demand during June and July could not possibly be operated economically with the decreased demands of May and August. This feature must always be given consideration.

The table seems to prove conclusively that the uniform continuous-flow method of delivery is exceedingly wasteful, for if a right called for a uniform continuous flow throughout the season with an allotment per acre of sufficient size to deliver the required amount during June and July, a large proportion of the quantity delivered could not be used economically and would be wasted during April, May, August, and September. While on the other hand, if the uniform continuous flow were of the size required to deliver the 2 acre-feet required during a six-months' or even a four-months' irrigation season, there still would be more water than is actually required during the early and late parts of the season and less than is actually required during

the months of June and July. Many instances have come to the attention of the writer where the advocates of a high duty have overlooked the unequal requirements of the different months of the season, and it is desired to emphasize the fact that this must not be ignored if the best use of the water is to be secured.

Table XVIII gives a general summary of the results that have been obtained upon porous, sandy, and gravelly soils. This table has been constructed by averaging the requirements of grain and alfalfa on these soils during the first two years of the investigation in the same manner used with the clay soils, there not having been a sufficient number of tracts of this type of soil experimented upon during the last two years of the investigation to be included in such a summary table.

TABLE XVIII.—*Average depths of water applied to 21 selected fields of grain and alfalfa on porous, sandy, and gravelly soils.*

[Altitudes ranging from 2,600 to 5,800 feet.]

| Crop. | Season. | Number of plots. | Depth of water applied. | | | | | | | | Total for season. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | April— | | May. | June. | July. | August. | September— | | |
| | | | 1–15 | 16–30 | | | | | 1–15 | 16–30 | |
| | | | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* |
| Alfalfa | 1910 | 7 | ...... | 0.53 | 1.12 | 1.69 | 1.96 | 1.13 | ...... | ........ | 6.43 |
| Grain | 1910 | 10 | ...... | ........ | .03 | 1.44 | .66 | .36 | ...... | ........ | 2.49 |
| Alfalfa | 1911 | 6 | ...... | .18 | .92 | 1.84 | 1.12 | 2.27 | 0.26 | ........ | 6.58 |
| Grain | 1911 | 8 | ...... | ........ | ...... | .90 | 1.06 | .94 | ...... | ........ | 2.90 |
| Average | ........ | ........ | ...... | .18 | .52 | 1.47 | 1.20 | 1.18 | .06 | ........ | 4.60 |
| Per cent of total | ........ | ........ | ...... | 3.9 | 11.3 | 32.0 | 26.0 | 25.6 | 1.3 | ........ | ........ |

Table XVIII shows that porous soils require a larger supply of water for their efficient irrigation than the medium soils, the exact quantity required being governed by the porosity of the soil, the method of preparation, and the skill used in the application of the water. The results shown in this table indicate that an application of 4.6 feet to the acre per annum will be required for this type of soil, of which 3.9 per cent will be required during the last half of April; 11.3 per cent during the month of May; 30 per cent during June; 26 per cent during July; 25.6 per cent during August; and 1.3 per cent during the first half of September.

### SURFACE WASTE.

The measurements just given do not include waste from irrigated lands. In the variation experiments the waste from the various plots was measured, with the results shown in Table XIX.

TABLE XIX.—*Percentage of total supply wasted from surface.*

| Crop. | Class of soil. | Number of irrigations. | Percentage of waste. | | |
|---|---|---|---|---|---|
| | | | Maximum. | Minimum. | Average. |
| | | | *Per cent.* | *Per cent.* | *Per cent.* |
| Alfalfa | Clay loam | 302 | 55.7 | 0.0 | 19.1 |
| Grain | do | 291 | 83.3 | 0.0 | 25.3 |
| Alfalfa | Gravelly | 147 | 24.8 | 0.0 | 1.8 |
| Grain | do | 122 | 31.4 | 0.0 | 2.3 |

Table XIX shows that over one-half of the water applied to grain and alfalfa upon clay loam soils is sometimes wasted, and that the average waste of the total quantity applied was 25.3 per cent for grain and 19.1 per cent for alfalfa. The above figures are based on the results from single fields, however, and irrigators should not be allowed to waste this percentage from their entire holdings. Irrigated farms should be so laid out that as much as possible of the waste water may be caught up and used over again on one or more fields before it is finally allowed to be wasted from the farm. It is safe to assume that the average farm could be so laid out that the water would not waste directly off the farm from over one-fourth its area. Rather steep farms, however, of small area, would suffer a larger waste than large farms or those with flatter slopes. Under normal Idaho conditions it is believed that all water contracts should provide for a sufficient delivery over and above the actual water requirements of the soils and crops so that the irrigator could waste between 7.5 and 12.5 per cent of the quantity delivered to him and still retain sufficient for his crop needs. The fact that present economic conditions will not justify a farmer in eliminating all waste must not be overlooked when designing new projects, and the contracts should provide for a delivery somewhat in excess of the actual needs of the soil and crops. This is not a serious factor when a project as a whole is considered, for at least one-half of the quantity wasted by the individual farmer can usually be caught up and measured out to other consumers.

### DEEP PERCOLATION WASTE.

That crops do not and can not utilize at the most more than 2.5 acre-feet per annum and that they probably utilize and transpire far less than this amount has been proved by the many large yields that have been made in the Idaho investigation with comparatively small supplies of water, and may also be seen from the curves in figures 3 and 4. Much of the water applied in excess of 2 to 2½ feet per acre in any region is lost through evaporation, surface waste, or deep percolation. With the more porous soils the loss from deep percolation beyond the reach of the plant roots is the greatest source

of waste from the fields, as well as the hardest one to overcome. That large losses are experienced from this source is proved by the fact that the ground water under almost all irrigated projects rises rapidly, the rise being either a seasonal or a permanent one. Where excellent underdrainage exists the water level usually recedes during the winter or nonirrigation season, but drainage of some sort is ultimately found necessary in at least a portion of most projects.

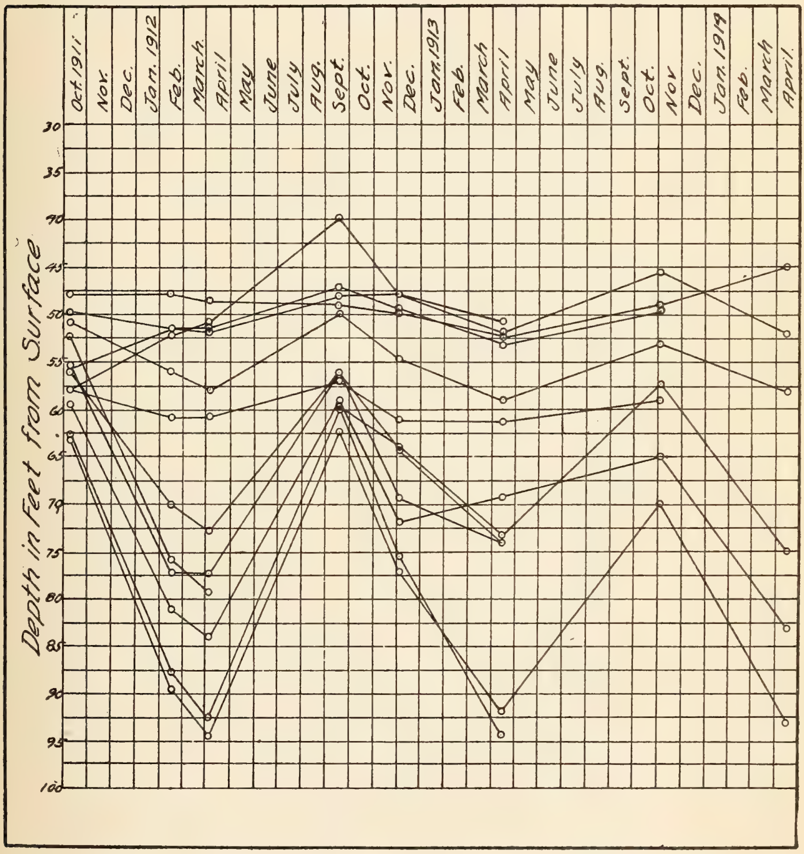



FIG. 10.—Variation in depth to water in wells in vicinity of Rigby, Idaho.

A typical case of the annual rise of water caused by deep percolation from porous irrigated land, there being excellent underdrainage from the land in question, is shown by the accompanying curves (fig. 10). These curves show the annual rise and fall of water in 13 wells in the vicinity of Rigby, Idaho, where there are 40,000 or 50,000 acres of porous irrigated land upon which large quantities of water are applied.

In order to demonstrate that a very large part of the irrigation water used in this locality was being lost by deep percolation, and to

show that light but rather frequent applications would give good results with these soils and that the application of water in this manner would result in a great saving of water, an experiment was carried on that it is believed has determined these factors in a satisfactory manner.

A water-tight galvanized-iron tank, 2 feet in diameter and 6 feet deep, with an outlet at the bottom terminating in a three-fourths inch galvanized-iron pipe 10 feet long, was installed in the soil flush with the surface of the ground. This tank was filled with 6 feet of soil in as near its original position as possible, three bands of hot asphaltum 1 foot wide were painted around the inside of the tank at 1-foot intervals to prevent percolation between the soil and the inside of the tank, after which the tank was irrigated each time an adjoining experimental plot was irrigated by applying the same amounts to the tank that were applied to the plot. Whatever water percolated through the 6 feet of soil in the tank drained out of the outlet pipe and was caught in a tub in a curbed pit 10 feet away. A total of 6.6 feet in depth in seven irrigations was applied to the experimental tract handled by the owner of the land and to the tank, and a quantity representing an equivalent of 5.5 feet per acre, or 83.5 per cent of the amount applied, percolated from the tank and was caught in the tub in the curbed pit, yet alfalfa which was planted on the tank when the experiment was started grew luxuriantly, demonstrating that the supply retained in the tank was adequate for the proper growth of the alfalfa. It was found that the tank during the season retained an average in its 6 feet of soil of 0.15 foot of water per acre for each application, and the experiment was continued during the following year, that of 1912, by irrigating the alfalfa in the tank whenever it appeared to require irrigation with 0.15 foot in depth at each application, no limit having been placed on the number of irrigations that were to be applied to the tank. It was found that the alfalfa in the tank required 10 irrigations during the season, and that there was but a trace of percolation from the tank. The alfalfa grown on the tank was cut, cured, and carefully weighed, and produced at the rate of 7.147 tons per acre, with an equivalent of 1.5 feet of water per acre plus a precipitation during the growing season of 8.51 inches. While this experiment was not conducted upon a scale broad enough to demonstrate the feasibility of this small amount of irrigation on large tracts or that this volume would produce the same comparative yield on them, it is believed, after taking into consideration the other observations, that it has been demonstrated that porous soils actually require but a very small supply at each application.

The securing of similar results from a practical application of the experiment just described requires a careful adaptation of methods of applying water to the types of soil to be irrigated. If an irrigation

system can be devised that will evenly apply a small quantity at each irrigation, porous soils can be irrigated and made to produce successful crops with no more water than is required for the irrigation of the medium or rather impervious soils.

### NUMBER OF IRRIGATIONS TO APPLY.

The number of irrigations required during the season is dependent upon the soil, climate, and class of crop. Other things being equal, porous soils which have a low water-holding capacity and the very impervious soils which absorb only small quantities at each application, will require irrigation oftener than soils of the medium types. Alfalfa and pasture grow throughout a longer season than the grains and consequently require more irrigations. The number of irrigations required during the season may vary from 1 on winter grain in the high altitudes of Montana to as many as 20 on alfalfa in southern California and Arizona, if the same be planted on porous soils. The number of irrigations required under conditions similar to those of Idaho is approximately three for grain and five for alfalfa. The average number applied in this investigation on all types of soils was 3.1 for all grains and 5.4 for alfalfa. Clean-cultivated orchards on deep soils of medium texture will seldom require more than two or three irrigations per annum. A safe rule to follow for hay and pasture grasses is to apply a sufficient number of light irrigations during the season so that plants will not wilt for lack of water.

### PROPER QUANTITY OF WATER TO APPLY AT EACH IRRIGATION.

A study of the tables included in this report shows that the volumes of water which have been applied to the various tracts at each irrigation have varied widely. It is not uncommon to find soils which are so impervious that they will absorb barely 0.1 to 0.15 foot in depth at each irrigation, or soils so porous that they can be made to absorb 1 to 3 feet in depth. The investigation has made it plain that a depth of 0.1 to 0.2 foot for one irrigation is insufficient if economy of water is desired, for the moisture forced into the soil does not last long enough, thus necessitating too many irrigations during the season. An unavoidable loss from evaporation invariably occurs during and immediately after each irrigation, and it is therefore desirable to apply as few irrigations during the season as will be required to maintain a sufficiently high moisture content in the soil for good plant growth. The investigation indicates that, generally speaking, from 3 to 6 acre-inches at one application is the correct quantity to apply and that impervious soils should be so manipulated that they can be made to absorb at least the smaller amount, while the porous soils should be so handled by using large irrigation heads that they can be

irrigated with not over 6 acre-inches at one application if economy of water is desired. It is hardly considered that it will ever be practical for the farmer to predetermine just how much should be applied at each irrigation and then apply this quantity and no more, but it is believed that intelligent and economical practice demands at least an approximate knowledge of the volume that is being applied. The fact that a head of 1 cubic foot per second delivers almost exactly 1 acre-inch per hour should make it comparatively easy for an irrigator to determine at least approximately how much water he applies to his land.

## LENGTH OF IRRIGATION SEASON.

The length of the season during which crops require water depends upon both the climate and the crops grown. Grains require water for only a comparatively short season, winter grains frequently requiring but one irrigation, while alfalfa and pasture grasses require irrigation from early spring until late fall. The climatic conditions, with particular reference to the temperature, which determines the length of the growing season, have a very direct influence upon the length of the irrigation season, since the grass crops, provided an abnormal amount of natural precipitation does not occur, will require water for as long as the climate will permit them to grow. The length of the irrigation season in Idaho has been carefully determined by the investigation and is shown for the different crops by Table XX.

TABLE XX.—*Average length of irrigation season of plots included in the 4 years' investigation.*

| Crop. | Year. | Total number of plots considered. | Average number of irrigations. | Number having 1 irrigation only. | Average length of irrigation season.[1] | Maximum length of irrigation season. | Average dates of irrigation. | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | First irrigation. | Last irrigation. |
| | | | | | *Days.* | *Days.* | | |
| Grains | 1910 | 76 | 3.6 | 3 | 46.0 | 87 | May 27 | July 12 |
| Alfalfa and clover | 1910 | 27 | 4.7 | 0 | 95.4 | 144 | May 12 | Aug. 12 |
| Grains | 1911 | 96 | 2.1 | 17 | 35.5 | 64 | June 13 | July 19 |
| Alfalfa and clover | 1911 | 34 | 6.1 | 1 | 111.4 | 142 | May 14 | Sept. 2 |
| Grains | 1912 | 60 | 3.7 | 10 | 39.7 | 61 | June 9 | July 18 |
| Alfalfa and clover | 1912 | 25 | 5.6 | 0 | 87.3 | 123 | May 23 | Aug. 18 |
| Grains | 1913 | 66 | 3.1 | 8 | 48.9 | 110 | June 5 | Aug. 20 |
| Alfalfa and clover | 1913 | 15 | 5.1 | 0 | 96.5 | 119 | May 16 | Do. |

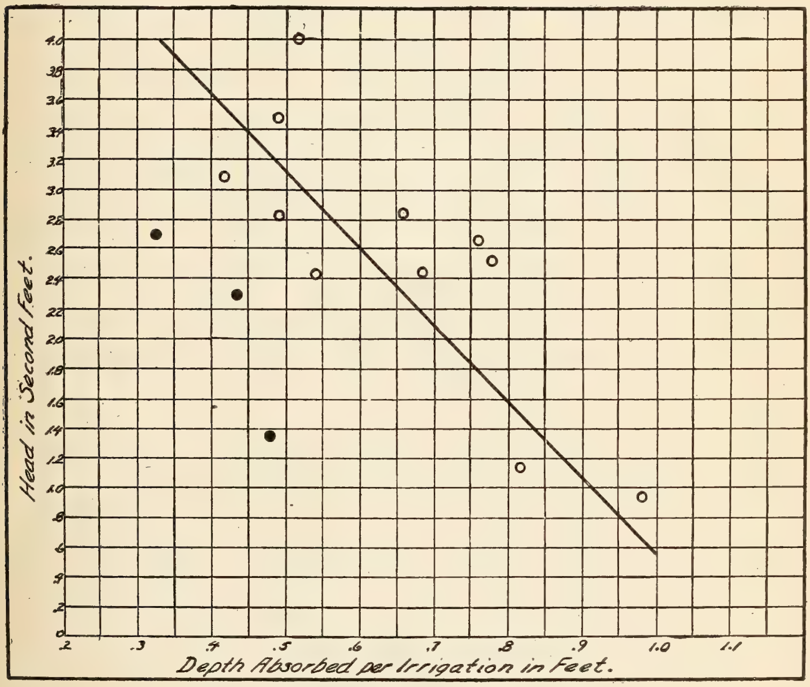
[1] Exclusive of plots having one irrigation only.

Average length of irrigation season for alfalfa for 4 years was 97.6 days.
Average length of irrigation season for grain for 4 years was 42.5 days.

## SIZE OF IRRIGATION HEAD.

The size of the irrigation head used, particularly with the porous soils, has a great effect upon the irrigation requirements. It is a fact well known to irrigators who are accustomed to handling porous soils that very little can be accomplished with small heads of water for

the reason that the water is absorbed so rapidly that it can not be forced over the field. Where water can be conducted in pipes or flumes to within 100 or 200 feet of the farthest part of the field to which it is to be applied, a method common among southern California orange growers, large heads are not necessary, but where surface irrigation is practised on large field units of porous or semiporous soil, the use of large heads is imperative if economy of water is to be secured. The lack of efficiency of small irrigation heads was shown by several of the experiments which were included in the investiga-




●=Soil more moist than normal prior to these irrigations.

FIG. 11.—Effect of size of irrigation head upon amount required per application, based upon results of an experiment upon 4.3 acres of porous gravelly loam soil in Boise Valley planted to pasture.

tion. The average size of the irrigation head which is used for nearly all purposes in the larger portion of Idaho seldom exceeds 1 to 2 second-feet, yet the use of heads three or four times this size would give a much higher efficiency, particularly if the soil is inclined to be at all porous. With rather impervious soils there is not such a loss in efficiency. The smaller the size of the head and the greater the distance water is run the larger the irrigation requirement. The accompanying curve (fig. 11) based on an experiment conducted by W. G. Steward, of the Boise project, United States Reclamation Service, clearly indicates the saving that may be made by using large heads for the irrigation of porous soils.

## LENGTH OF RUN.

Water never should be flooded too far between cross ditches on any crop or on any class of soil. An even application of water to all parts of a field is highly desirable but is very difficult to secure even with the best of systems in use. Where water is run too far between cross ditches there is either oversaturation and deep percolation loss on the upper end near the supply ditch, or insufficient absorption at the lower end near the waste ditch. This is particularly true with soils which absorb water readily. Other things being equal, water

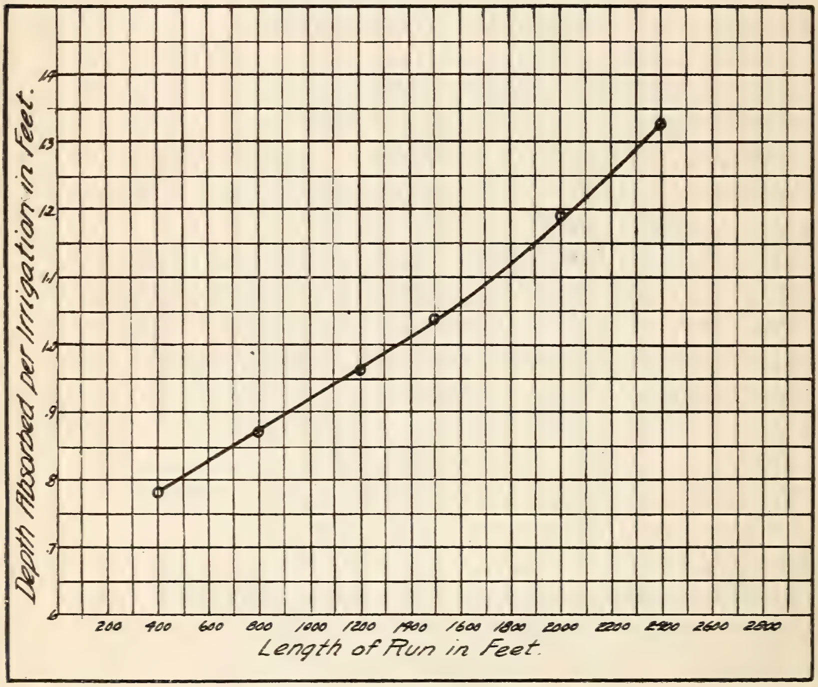



FIG. 12.—Effect of length of run upon amount required per application. (Based upon results from 20 different plots of porous soil.)

should be flooded shorter distances on porous soils than on the more impervious soils. Experiments conducted upon 20 plots of very porous soil in the vicinity of Rigby, Idaho, have demonstrated that a very great saving of water may be made by flooding shorter distances than is usual, and it is thought that a preparation of the land into narrower, shorter borders, and the use of larger heads would have resulted in a still greater saving. The curve in figure 12 is self-explanatory and clearly illustrates the great saving of water which may be made on porous soils similar to those near Rigby (Pl. II, fig. 2) by flooding water shorter distances.

### FALL PLOWING.

An experiment was carried on at the Gooding experiment station to determine the effect of fall versus spring plowing on the duty of water and yield produced, with the results that are shown in Table XXI.

TABLE XXI.—*Results of fall versus spring plowing, Gooding experiment station.*

| Sub-plot No. | Area. | Treatment of subplot. | Water applied per acre. | Yield of grain. | | Weight of grain per bushel. |
|---|---|---|---|---|---|---|
| | | | | Per acre. | Per acre-foot of water. | |
| | *Acre.* | | *Acre-feet.* | *Bush.* | *Bush.* | *Pounds.* |
| 1 | 0.314 | Fall plowed, minimum irrigation | 0.376 | 41.18 | 109.5 | 38 |
| 2 | .315 | Spring plowed, minimum irrigation | .376 | 32.88 | 87.5 | 38 |
| 3 | .314 | Fall plowed, average irrigation | .962 | 43.65 | 45.5 | 41 |
| 4 | .314 | Spring plowed, average irrigation | .962 | 39.77 | 41.4 | 41 |
| 5 | .304 | Fall plowed, maximum irrigation | 1.533 | 47.54 | 31.0 | 42 |
| 6 | .305 | Spring plowed, maximum irrigation | 1.533 | 45.26 | 29.5 | 42 |

A study of Table XXI makes it apparent that too much emphasis can hardly be placed on the many advantages of fall plowing.

### MEASUREMENT OF WATER USED ON FARMS AND UNDER COMPLETE CANAL SYSTEMS.

It is believed that the supply of water has been varied upon a sufficient number of tracts in this investigation and that the investigation has covered a sufficient number of seasons to furnish a correct idea of the irrigation requirements of the soils and crops included, but as an investigation of this sort alone furnishes no information (1) of the water required for domestic purposes, (2) of the transmission losses and other general wastes, or (3) of the average use of water on typical Idaho farms when such use is unrestricted, it was thought best to investigate also the use of water both upon typical farms and under complete canal systems of the State. The investigation was therefore extended so as to include a careful measurement of the quantities used by a large number of typical farmers and by seven complete canal systems in 1911 and eight complete canal systems in 1912.

The water used on the farms investigated was measured by automatic water registers which were installed on weirs in the feed ditches leading to the tracts or farms in question. The type of water registers used and the method of their installation in connection with the weirs are shown in Plate III, figure 1.

The volume of water diverted and used by the canal systems was determined by daily gage readings and a large number of current-

meter determinations at the head of the main canal of each system (Pl. III, fig. 2). The gages were read by men employed for the purpose, and the discharge curves were based in each case upon 20 to 30 current-meter ratings which were made during the season at each station by two to six hydrographers with different meters. The areas irrigated under each system and the crops that were grown were determined by a house-to-house canvass of each farm.

### BOISE VALLEY FARMS.

The quantity of water delivered to a total of 428.64 acres on 16 farms in the Boise Valley was determined during the season of 1912. The farms included were located in the heart of the valley, near Meridian, and represented typical Boise Valley conditions, and the average use of water at the individual farmer's head gates in the district during the season was found to be 2.56 feet per acre, the quantity wasted not having been deducted. Of the 428.64 acres included, 144.84 acres were devoted to alfalfa, pasture, and other hay grasses, the remainder to grains, potatoes, and orchards. The soil of the district is nearly uniform and consists of a clay loam 3 to 8 feet in depth, underlain with a rather compact gravel. The water for irrigation purposes in the above district is used with more than the average care, and the use of water shown by the measurements corresponds very closely with the requirements shown by the variation experiments.

### SALMON RIVER PROJECT FARMS.

The water applied to a total of 978.22 acres on 12 farms of the Salmon River project was measured during the season of 1913, the area involved having all been determined by transit surveys. The soil of the district is a clay loam 2 to 6 feet in depth underlain by lava rock. The total area involved consisted of 200.73 acres of hay and pasture grasses, and 777.49 acres of grain, potatoes, and orchards, and the use of water by the farmers varied from 0.77 to 5.30 acre-feet and averaged 2.08 acre-feet for the entire area. This was the first year some of this land had been irrigated, and it is believed the 2.08 acre-feet, with one or two exceptions, represented the average use of water on the entire project at that time. The quantities wasted from these tracts were not measured.

### WATER DIVERTED BY TYPICAL CANAL SYSTEMS.

The canal systems investigated in order to determine their headgate diversions consisted of the Riverside, Farmers' Cooperative, Farmers' Union, Settlers', Boise Valley, Pioneer, and Eureka, typical canals of the Boise Valley; the Randall Canal, and the Clark and Edwards in the Upper Snake River Valley; and the South Side Twin Falls Canal, which irrigates approximately 200,000 acres on the

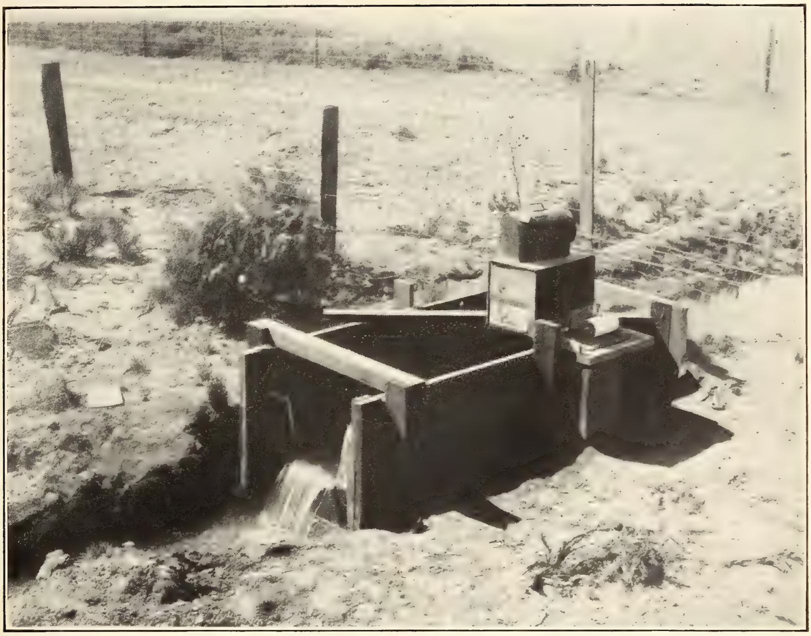


FIG. 1.—TYPE OF WATER REGISTER USED IN THE IDAHO INVESTIGATION, SHOWING THE METHOD OF INSTALLATION.

FIG. 2.—METHOD OF RATING LARGE CANALS.

south side of Snake River in Twin Falls County. Of the Boise Valley canals the Riverside, Farmers' Cooperative, Farmers' Union, and Settlers' irrigate clay loam bench soils almost exclusively, while the Boise Valley, Pioneer, and Eureka irrigate the more porous sandy loam and gravelly bottom soils. The ground water usually lies rather close to the surface under the lands irrigated by the bottom canals. The Randall and the Clark and Edwards canals irrigate very gravelly soil in the upper Snake River Valley, the gravel being of a very porous nature to a depth of at least 80 feet, at which depth the ground water is found. The South Side Twin Falls Canal irrigates approximately 200,000 acres of gently rolling clay loam soils with an average slope of about 50 feet per mile, the soil underlain with lava rock and ranging from 2 to 40 feet in depth, with a probable average of 8 feet. The data secured from these canal systems during the Idaho investigation are shown in a condensed form in tables XXII and XXIII, which follow. The volumes diverted by the canals during the season of 1911 were measured by W. G. Steward, of the United States Reclamation Service, and the remainder of the data was secured by our own assistants.

Table XXII shows areas devoted to different crops under the canals investigated:

TABLE XXII.—*Acreage devoted to different crops, and percentage of areas actually irrigated under ten different canals.*

| Name of canal. | Year. | Hay. | | Pasture. | | Grain. | | Orchard.[1] | | Total. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Acres. | Per cent. | Acres. | Per cent. | Acres. | Per cent. | Acres. | Per cent. | |
| Riverside | 1911 | 4,059.00 | 54.7 | 175.25 | 2.4 | 911.00 | 12.2 | 2,280.25 | 30.7 | 7,425.50 |
| Do | 1912 | 3,455.75 | 50.1 | 627.25 | 9.1 | 1,360.00 | 19.7 | 1,455.50 | 21.1 | 6,898.50 |
| Farmers' Cooperative | 1911 | 5,526.75 | 44.4 | 1,626.00 | 13.1 | 2,043.50 | 16.4 | 3,239.00 | 26.1 | 12,435.25 |
| Do | 1912 | 4,890.00 | 37.4 | 2,289.50 | 17.5 | 2,354.25 | 18.0 | 3,528.66 | 27.1 | 13,062.41 |
| Farmers' Union | 1911 | 3,339.44 | 48.8 | 1,171.94 | 17.1 | 1,526.94 | 22.3 | 804.38 | 11.8 | 6,842.70 |
| Do | 1912 | 3,045.35 | 42.6 | 1,534.74 | 21.5 | 1,737.00 | 24.3 | 827.33 | 11.6 | 7,144.42 |
| Settlers' | 1911 | 4,385.25 | 37.1 | 2,157.25 | 18.2 | 3,686.50 | 31.2 | 1,590.80 | 13.5 | 11,819.80 |
| Do | 1912 | 4,490.25 | 38.2 | 1,848.20 | 15.7 | 3,294.75 | 28.0 | 2,121.80 | 18.1 | 11,755.00 |
| Boise Valley | 1911 | 332.25 | 14.9 | 1,189.09 | 53.4 | 277.80 | 12.5 | 426.35 | 19.2 | 2,225.49 |
| Do | 1912 | 267.00 | 11.7 | 1,222.50 | 53.4 | 336.00 | 14.7 | 461.50 | 20.2 | 2,287.00 |
| Eureka | 1911 | 369.00 | 17.9 | 1,138.75 | 55.2 | 505.00 | 24.5 | 49.25 | 2.4 | 2,062.00 |
| Pioneer | 1911 | 115.25 | 10.2 | 667.67 | 59.3 | 197.90 | 17.6 | 145.72 | 12.9 | 1,126.54 |
| Do | 1912 | 132.50 | 11.5 | 689.32 | 60.0 | 166.75 | 14.5 | 160.17 | 14.0 | 1,148.74 |
| Randall | 1912 | 1,193.50 | 36.6 | 207.50 | 6.4 | 1,145.00 | 35.2 | 709.00 | 21.8 | 3,255.00 |
| Clark and Edwards | 1912 | 570.00 | 41.9 | 97.00 | 7.1 | 463.50 | 34.0 | 232.00 | 17.0 | 1,362.50 |
| South Side Twin Falls | 1912 | 59,229.00 | 40.2 | 10,094.00 | 6.8 | 56,379.00 | 38.3 | 21,607.00 | 14.7 | 147,309.00 |
| Do | 1913 | 54,903.00 | 36.8 | 12,212.00 | 8.2 | 60,805.00 | 40.7 | 21,391.00 | 14.3 | 149,311.00 |
| Total | ...... | 150,303.29 | ...... | 38,947.96 | ...... | 137,189.89 | ...... | 61,029.71 | ...... | 387,470.85 |
| Average per cent | ...... | ............ | 38.8 | ............ | 10.1 | ............ | 35.4 | ............ | 15.7 | 100.00 |

[1] Includes small fruits, garden, potatoes, and home grounds.

Table XXII includes no uncleared land, but only the areas actually irrigated under each canal system investigated, and shows that 38.8 per cent of the area was devoted to hay, 10.1 per cent to pasture, 35.4 per cent to grain, and 15.7 per cent to orchard and miscellaneous

crops. The table confirms the conclusion reached from Table X, that normal projects are about equally divided between (1) hay and pasture and (2) grain and other miscellaneous crops.

The number of acre-feet diverted each month by each system was determined and computed, and Table XXIII shows the number of acre-feet diverted for each acre irrigated during each month of each season.

TABLE XXIII.—*Quantity of water diverted for each acre irrigated during each month of irrigation season for ten different canals.*

| Name of canal. | Year. | Acre-feet diverted for each acre irrigated. | | | | | | | | | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | April— | | May. | June. | July. | August. | September. | October— | | |
| | | 1–15 | 16–30 | | | | | | 1–15 | 16–31 | |
| Riverside | 1911 | 0.08 | 0.43 | 1.40 | 1.46 | 1.54 | 0.79 | 0.79 | 0.50 | 0.15 | 7.14 |
| Do | 1912 | .11 | .63 | 1.74 | 1.98 | 1.99 | 1.19 | 1.23 | .62 | .00 | 9.49 |
| Farmers' cooperative | 1911 | .04 | .38 | 1.31 | 1.36 | 1.16 | .44 | .36 | .28 | .19 | 5.52 |
| Do | 1912 | .00 | .08 | 1.07 | 1.26 | .94 | .58 | .56 | .17 | .10 | 4.76 |
| Farmers' Union | 1911 | .14 | .48 | 1.25 | 1.41 | 1.25 | .55 | .45 | .13 | .00 | 5.66 |
| Do | 1912 | .25 | .68 | 1.32 | 1.23 | 1.07 | .53 | .45 | .00 | .00 | 5.53 |
| Settlers' | 1911 | .04 | .16 | .42 | .72 | .71 | .46 | .42 | .11 | .00 | 3.04 |
| Do | 1912 | .00 | .01 | .49 | .69 | .70 | .54 | .34 | .10 | .00 | 2.87 |
| Boise Valley | 1911 | .14 | .27 | .63 | .59 | .64 | .42 | .30 | .12 | .00 | 3.11 |
| Do | 1912 | .00 | .00 | .46 | .50 | .68 | .38 | .37 | .00 | .00 | 2.39 |
| Eureka | 1911 | .00 | .05 | .38 | .33 | .34 | .35 | .34 | .03 | .02 | 1.84 |
| Pioneer | 1911 | .11 | .40 | .91 | .97 | 1.09 | 1.01 | .83 | .12 | .00 | 5.44 |
| Do | 1912 | .14 | .00 | 1.12 | 1.62 | 1.03 | .98 | .82 | .31 | .00 | 6.02 |
| Randall | 1912 | .00 | .00 | .00 | 1.58 | 2.25 | 1.99 | .81 | .25 | .00 | 6.88 |
| Clark and Edwards | 1912 | .00 | .00 | .31 | 2.59 | 3.00 | 2.67 | 2.04 | .34 | .00 | 10.95 |
| South Side Twin Falls | 1912 | .10 | .14 | .60 | 1.10 | 1.23 | 1.13 | .61 | .22 | .16 | 5.29 |
| Do | 1913 | .09 | .11 | .83 | 1.12 | 1.25 | 1.21 | .73 | .20 | .17 | 5.71 |
| Average for month | | .08 | .22 | .84 | 1.21 | 1.23 | .89 | .67 | .20 | .05 | 5.39 |
| Per cent of season's diversion | | 1.49 | 4.08 | 15.6 | 22.43 | 22.83 | 16.5 | 12.43 | 3.71 | .93 | 100.00 |

The investigation has demonstrated the adequacy of 2 acre-feet (p. 32) for diversified crops on clay loam soils, provided there is no waste, and the measurements of the use of water by the farmers in typical districts show that more than 2.5 feet per acre is seldom delivered to or used upon the land. The quantities diverted by the above projects, however, which represent the normal use in Idaho, show that they divert much more than is required for the crops on the farm. A comparison of these diversions with the quantities required and used on the farms would indicate (1) that water is wasted by the canal systems both early and late in the season; (2) that a considerable supply is required for domestic purposes and stock water; and (3) that the losses from seepage and evaporation in transmission, and from careless use, must be far larger than many have realized. The quantities shown as having been diverted per acre in the preceding tables are known to be very nearly accurate, and, considering the fact that it has been found necessary to divert these quantities under normal Idaho conditions, these data must be given careful consideration when designing projects with scanty water supplies.

## SEEPAGE INVESTIGATION.

The losses to which the waters of an irrigation project are subject in passing from the point of diversion to the land to be irrigated have not always been given sufficient consideration in the designing of projects. It became evident early in the investigation that the losses to which canals in different types of soil are subjected should be measured in order to determine how much water should be diverted to deliver the quantity required. During the years 1912 and 1913, 118 sections of Idaho canals were measured for the determination of the seepage losses. These canals varied in discharge from 0.07 cubic foot per second to over 3,190 cubic feet per second, and in cross section from 0.117 square foot to 984 square feet. A total of 287.31 linear miles was included, covering all of the common soil types of Idaho, and it is believed sufficient data have been secured to furnish a substantial basis for estimating the losses to which the canals of this State will be subject.

### METHOD OF INVESTIGATION.

All canals included in the investigation with a discharge of 3 second-feet and less were measured with Cipolletti weirs installed at the upper and lower ends of each section. The head on these weirs was read to the nearest 0.001 foot with small inexpensive hook gages that were especially designed for the purpose. All canals with a greater discharge than 3 second-feet were measured with current meters. The 0.2, 0.6, and 0.8, or 3-point, method of measurement was used in all cases where the canal exceeded 1 foot in depth, and either the 0.6, or integration, method with the shallower canals. In order to eliminate errors in computation, individual characteristics of the meters, and personal equation of the men, every section measured with current meters was measured by at least two hydrographers, each with a different meter, thus furnishing a double check on all results. It was found that fluctuations of gage height and discharge were the most troublesome factor in connection with seepage determinations, and the following method was used for the elimination of the effect of the fluctuations:

Canals to be included in the investigation were thoroughly looked over before any ratings were made, and gages which could be read to the nearest 0.02 foot were installed approximately every 2 miles in the main canal and at the head of all diversions, care being used to pick good sections in the middle or in the lower third of as long a tangent as possible. Discharge curves were plotted for each station by using the bottom of the canal as the zero or point of no flow, and the point at which water stood when the measurement was made as the only other point that was determined for each curve, care

being used to make them conform as nearly as possible to standard curves for similar sections. After all of the measurements had been made, floats consisting of tightly corked bottles were dropped into the main canal at the upper gage, and a man proceeded down with them, reading each gage in the main canal and at the head of all diversions at the time the floats passed. Other men with more floats followed the first ones at 2 to 3 hour intervals during the day. The discharges at the different stations and the consequent seepage losses between were determined from the gage heights at the time the floats passed, thus minimizing error from fluctuations in gage height. This method compares losses from the same flow or wave of water for a 12 or 14 hour period, and while the rating curves based on only two points may be slightly inaccurate, the canals were held quite uniform throughout the entire investigation.

The larger canals were measured either from cars which were suspended from cables across the stream or from a boat especially fitted up for the purpose (Pl. III, fig. 2). The smaller canals, where convenient bridges could be found, were rated from the bridges, and in other cases, where the depth permitted, wading measurements were made.

There are two common methods of expressing seepage losses. One is per cent of flow lost per mile, and the other the number of cubic feet lost from each square foot of wetted canal bed in 24 hours. The former and older method is more readily calculated and understood, but since the percentage decreases rapidly as the capacity is increased, many prefer the use of the latter unit, as it is more constant for any type of soil and largely independent of the capacity of the canal. Table XXIV gives the results of measurements of seepage losses. For convenience, the losses are expressed by both methods.

TABLE XXIV.—*Seepage losses from canals.*

| No. | Average width of water surface. | Area water surface. | Wetted perimeter. | Discharge at upper end of section. | Total loss in section. | Length of section observed. | Loss per mile. | Loss per square foot wetted area per 24 hours. | Loss per mile. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Feet.* | *Square feet.* | *Feet.* | *Second-feet.* | *Second-feet.* | *Miles.* | *Second-feet.* | *Cubic feet.* | *Per cent.* | |
| 1 | 0.9 | 0.12 | 1.0 | 0.07 | 0.02 | 0.490 | 0.04 | 0.666 | 57.1 | Medium clay loam. |
| 2 | 1.0 | .16 | 1.2 | .14 | .02 | .399 | .05 | .684 | 35.7 | Do. |
| 3 | 1.4 | .19 | 1.5 | .20 | .04 | .700 | .06 | .623 | 30.0 | Deep clay loam. |
| 4 | 1.5 | .32 | 1.7 | .28 | .08 | .682 | .12 | 1.129 | 42.9 | Clay loam, gravel. |
| 5 | 1.5 | .42 | 1.8 | .36 | .08 | .379 | .21 | 1.919 | 58.3 | Do. |
| 6 | 1.5 | .48 | 1.9 | .53 | .07 | .714 | .10 | .844 | 18.9 | Clay loam, hardpan. |
| 7 | 1.0 | .28 | 1.4 | .54 | .07 | .740 | .10 | 1.107 | 18.5 | Deep medium clay loam. |
| 8 | 1.5 | .22 | 1.6 | .58 | .03 | .378 | .08 | .811 | 13.8 | Shallow clay loam. |
| 9 | 1.8 | .45 | 2.3 | .68 | .03 | .469 | .06 | .455 | 8.8 | Impervious clay loam. |
| 10 | 1.9 | .43 | 2.1 | .80 | .13 | .528 | .25 | 1.919 | 31.3 | Medium clay loam. |
| 11 | 1.5 | .35 | 1.7 | .84 | .03 | .422 | .01 | .659 | 4.3 | Do. |
| 12 | 1.5 | .52 | 2.2 | .85 | .12 | .435 | .28 | 2.052 | 32.9 | Porous medium clay loam. |
| 13 | 1.3 | .36 | 1.6 | .87 | .04 | .573 | .07 | .714 | 8.0 | Deep clay loam. |
| 14 | 3.5 | .96 | 3.7 | .99 | .07 | .519 | .14 | .596 | 14.1 | Clay loam, hardpan. |

TABLE XXIV.—*Seepage losses from canals*—Continued.

| No. | Average width of water surface. | Area water surface. | Wetted perimeter. | Discharge at upper end of section. | Total loss in section. | Length of section observed. | Loss per mile. | Loss per square foot wetted area per 24 hours. | Loss per mile. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Feet.* | *Square feet.* | *Feet.* | *Second-feet.* | *Second-feet.* | *Miles.* | *Second-feet.* | *Cubic feet.* | *Per cent.* | |
| 15 | 1.8 | 0.52 | 2.1 | 1.12 | 0.10 | 0.480 | 0.21 | 1.623 | 19.8 | Porous clay loam, hardpan. |
| 16 | 2.5 | 1.0 | 2.9 | 1.22 | .10 | 1.534 | .06 | .368 | 4.9 | Impervious clay loam. |
| 17 | 2.0 | .58 | 2.3 | 1.28 | .01 | .351 | .03 | .203 | 2.3 | Uniform clay loam. |
| 18 | 4.3 | 1.2 | 4.6 | 1.28 | .09 | 1.623 | .06 | .191 | 4.7 | Impervious clay loam. |
| 19 | 1.8 | .72 | 2.6 | 1.41 | .12 | .316 | .38 | 2.390 | 27.0 | Porous clay loam. |
| 20 | 3.6 | 1.2 | 4.0 | 1.45 | .56 | 5.254 | .11 | .436 | 7.6 | Clay and sandy loam. |
| 21 | 3.4 | .78 | 3.9 | 1.48 | .13 | .553 | .24 | .986 | 16.2 | Clay loam, shale bottom. |
| 22 | 3.0 | 2.6 | 4.0 | 1.91 | .36 | .662 | .54 | 2.225 | 28.3 | Sandy loam. |
| 23 | 2.4 | .82 | 2.8 | 2.0 | .26 | .945 | .28 | 1.608 | 14.0 | Clay loam, hardpan. |
| 24 | 3.0 | 1.4 | 3.9 | 2.0 | .23 | .352 | .65 | 2.742 | 32.5 | Limestone shale bottom. |
| 25 | 2.2 | 1.1 | 3.2 | 2.1 | .10 | .420 | .24 | 1.218 | 11.4 | Compact impervious clay. |
| 26 | 3.0 | .92 | 3.3 | 2.2 | .05 | .554 | .09 | .448 | 4.1 | Shallow clay loam. |
| 27 | 2.4 | .91 | 2.8 | 2.2 | .06 | .659 | .09 | .532 | 4.1 | Medium clay loam, hardpan. |
| 28 | 2.5 | 1.1 | 3.0 | 2.3 | .10 | .576 | .17 | .947 | 7.4 | Medium clay loam. |
| 29 | 5.4 | 3.7 | 6.0 | 3.8 | .18 | 1.175 | .15 | .418 | 3.9 | Sandy loam and gravel. |
| 30 | 7.9 | 5.0 | 8.3 | 4.5 | .44 | 2.020 | .22 | .429 | 4.9 | Impervious clay loam. |
| 31 | 6.4 | 2.4 | 6.5 | 5.2 | .21 | 2.650 | .08 | .184 | 1.5 | Do. |
| 32 | 8.3 | 6.1 | 8.8 | 5.4 | .88 | 1.980 | .44 | .826 | 8.1 | Porous clay loam. |
| 33 | 7.5 | 4.6 | 7.9 | 6.2 | .49 | 2.010 | .24 | .505 | 3.9 | Clay loam, compacted. |
| 34 | 3.9 | 3.6 | 5.5 | 5.4 | .96 | .498 | 1.93 | 5.735 | 35.7 | Very porous gravel. |
| 35 | 4.6 | 4.4 | 5.8 | 6.1 | .46 | .584 | .79 | 2.222 | 13.0 | Do. |
| 36 | 7.7 | 4.6 | 8.0 | 6.8 | .84 | 1.984 | .42 | .868 | 6.2 | Clay loam, some rock. |
| 37 | 8.6 | 5.0 | 8.8 | 7.1 | .50 | 3.944 | .13 | .236 | 1.8 | Impervious clay loam. |
| 38 | 8.1 | 4.3 | 8.4 | 7.2 | .38 | 1.460 | .26 | .507 | 3.6 | Sandy clay loam. |
| 39 | 7.3 | 4.6 | 7.8 | 7.8 | .17 | 1.950 | .09 | .183 | 1.2 | Shallow clay loam. |
| 40 | 9.8 | 5.0 | 10.5 | 8.1 | .54 | 3.010 | .18 | .280 | 2.2 | Clay loam. |
| 41 | 7.5 | 6.3 | 8.0 | 8.9 | .85 | .520 | 1.64 | 3.344 | 18.4 | Medium gravel. |
| 42 | 8.8 | 5.0 | 9.1 | 9.6 | .46 | 1.968 | .23 | .420 | 2.4 | Clay loam, silt. |
| 43 | 9.7 | 5.0 | 10.0 | 10.0 | .17 | 2.560 | .07 | .109 | .7 | Do. |
| 44 | 13.3 | 7.3 | 14.1 | 10.8 | 1.18 | 3.000 | .39 | .456 | 2.8 | Clay loam, rock. |
| 45 | 5.8 | 7.9 | 7.5 | 11.1 | 1.15 | 1.790 | .64 | 1.402 | 5.8 | Uniform clay loam. |
| 46 | 7.2 | 10.3 | 9.2 | 12.5 | 1.57 | 1.255 | 1.25 | 2.225 | 10.0 | Medium gravel. |
| 47 | 9.5 | 9.4 | 10.1 | 13.2 | .94 | 1.309 | .72 | 1.163 | 5.5 | Gravelly clay loam. |
| 48 | 11.9 | 9.6 | 12.8 | 13.3 | 1.14 | 1.970 | .58 | .690 | 4.4 | Deep clay loam. |
| 49 | 11.1 | 7.1 | 12.0 | 14.7 | 3.5 | 2.612 | 1.34 | 1.827 | 9.1 | Deep sandy loam. |
| 50 | 9.6 | 8.0 | 10.3 | 15.2 | −1.52 | 1.780 | .85 | ........ | 5.6 | Irrigated land above. |
| 51 | 6.3 | 5.9 | 7.3 | 17.0 | .87 | 1.840 | .47 | 1.061 | 2.8 | Compact clay loam. |
| 52 | 8.6 | 11.6 | 9.9 | 18.5 | 1.35 | .674 | 2.0 | 3.311 | 10.8 | Medium gravel. |
| 53 | 8.3 | 11.1 | 9.9 | 19.0 | 1.84 | 3.680 | .50 | .801 | 2.6 | Impervious clay loam. |
| 54 | 10.3 | 10.0 | 11.2 | 19.3 | 1.81 | 4.568 | .40 | .579 | 2.1 | Gravelly clay loam. |
| 55 | 11.2 | 11.0 | 11.7 | 21.7 | 2.3 | 3.812 | .60 | .876 | 2.8 | Clay loam, silt. |
| 56 | 10.8 | 10.2 | 11.5 | 22.1 | 2.5 | 1.830 | 1.37 | 1.944 | 6.2 | Heavy sandy clay loam. |
| 57 | 20.4 | 16.5 | 21.4 | 24.0 | 5.0 | 1.936 | 2.6 | 1.975 | 10.8 | Sandy loam. |
| 58 | 12.2 | 16.8 | 13.2 | 24.2 | 1.11 | .478 | 2.3 | 2.879 | 9.5 | Very gravelly. |
| 59 | 27.3 | 32.2 | 28.2 | 31.2 | 1.43 | 3.770 | .38 | .220 | 1.2 | Deep clay loam, silt. |
| 60 | 8.9 | 13.0 | 11.2 | 41.1 | 4.8 | 3.171 | 1.51 | 2.212 | 3.8 | Very gravelly. |
| 61 | 29.5 | 27.0 | 30.0 | 43.0 | 5.0 | 2.210 | 2.3 | 1.234 | 5.3 | Hardpan, shale. |
| 62 | 19.8 | 28.7 | 20.8 | 43.6 | 1.35 | 1.881 | .72 | .565 | 1.7 | Deep clay loam. |
| 63 | 19.7 | 31.1 | 20.8 | 45.5 | 1.90 | 1.746 | 1.09 | .856 | 2.4 | Do. |
| 64 | 19.5 | 33.4 | 20.6 | 50.3 | 4.8 | 3.000 | 1.60 | 1.271 | 3.2 | Do. |
| 65 | 26.9 | 29.2 | 26.6 | 54.2 | 2.4 | 3.320 | .72 | .445 | 1.3 | Gravelly hillside. |
| 66 | 21.7 | 39.8 | 22.7 | 59.0 | 8.7 | 4.533 | 1.92 | 1.384 | 3.3 | Deep clay loam. |
| 67 | 24.4 | 39.8 | 25.5 | 68.1 | .76 | 3.140 | .24 | 1.553 | 3.4 | Shallow clay loam. |
| 68 | 24.8 | 52.7 | 25.9 | 73.0 | 14.0 | 4.862 | 2.9 | 1.819 | 4.0 | Deep clay loam. |
| 69 | 12.5 | 27.6 | 15.2 | 77.0 | 1.44 | 1.660 | .87 | .934 | 1.1 | Impervious clay loam. |
| 70 | 45.0 | 58.3 | 46.3 | 78.6 | 5.9 | 2.928 | 2.0 | .712 | 2.5 | Medium clay loam. |
| 71 | 30.0 | 43.5 | 30.5 | 79.5 | 2.9 | 3.320 | .87 | .469 | 1.1 | Gravelly sidehill. |
| 72 | 14.8 | 30.8 | 17.4 | 91.5 | 2.2 | 1.570 | 1.40 | 1.317 | 1.5 | Uniform clay loam. |
| 73 | 23.3 | 45.8 | 24.5 | 92.2 | 3.4 | 3.138 | 1.08 | .724 | 1.2 | Medium clay loam. |
| 74 | 14.3 | 40.6 | 18.4 | 93.9 | .14 | 1.800 | .08 | .069 | 0.9 | Clay loam irrigated land. |
| 75 | 15.5 | 46.5 | 20.0 | 106 | −4.5 | 2.100 | 2.1 | ........ | 2.0 | Ground water near surface. |
| 76 | 20.7 | 37.1 | 22.0 | 112 | 2.6 | 2.630 | 1.00 | .735 | 0.9 | Uniform clay loam. |
| 77 | 23.3 | 46.4 | 24.8 | 122 | 6.0 | 1.980 | 3.0 | 1.999 | 2.5 | Gravelly sidehill. |
| 78 | 23.5 | 53.3 | 25.4 | 127 | 12.1 | 3.140 | 3.9 | 2.482 | 3.1 | Medium clay loam shale ½ disintegrated. |
| 79 | 45.0 | 73.9 | 47.0 | 133 | 1.90 | 2.930 | .65 | .226 | 0.5 | Medium clay loam. |
| 80 | 17.0 | 42.2 | 21.0 | 136 | 9.4 | 2.833 | 3.3 | 2.585 | 2.4 | Sand and gravel. |
| 81 | 38.0 | 99.5 | 40.0 | 140 | 11.3 | 4.960 | 2.3 | .932 | 1.6 | Shallow clay loam. |
| 82 | 37.0 | 94.8 | 38.6 | 146 | 5.8 | 6.260 | .92 | .393 | 0.6 | Do. |
| 83 | 18.3 | 52.4 | 22.4 | 146 | 10.5 | 3.400 | 3.1 | 2.256 | 2.1 | Heavy clay loam. |
| 84 | ...... | ........ | ...... | 175 | 1.31 | 13.000 | .10 | ........ | 0.1 | Perrine coulee. |
| 85 | 67.5 | 116 | 68.2 | 192 | 2.3 | 3.809 | .60 | .145 | 0.3 | Clay loam and lava. |

TABLE XXIV.—*Seepage losses from canals*—Continued.

| No. | Average width of water surface. | Area water surface. | Wetted perimeter. | Discharge at upper end of section. | Total loss in section. | Length of section observed. | Loss per mile. | Loss per square foot wetted area per 24 hours. | Loss per mile. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Feet.* | *Square feet.* | *Feet.* | *Second-feet.* | *Second-feet.* | *Miles.* | *Second-feet.* | *Cubic feet.* | *Per cent.* | |
| 86 | 68.1 | 125 | 68.8 | 207 | 8.4 | 4.185 | 2.0 | 0.480 | 1.0 | Clay loam, hardpan, lava rock. |
| 87 | 22.4 | 67.7 | 27.0 | 214 | 10.2 | 3.090 | 3.3 | 2.001 | 1.5 | Gravel and clay loam. |
| 88 | 21.3 | 97.5 | 27.5 | 242 | 1.33 | 3.530 | .38 | .224 | 0.2 | Heavy gravel. |
| 89 | 26.4 | 91.6 | 31.0 | 243 | 3.6 | 1.920 | 1.88 | .988 | 0.8 | Compact clay loam. |
| 90 | 21.0 | 96.0 | 28.8 | 244 | .13 | 3.500 | .04 | .021 | 0.01 | Banks sandy. |
| 91 | 21.9 | 101.4 | 30.8 | 260 | 10.0 | 2.450 | 4.1 | 2.048 | 1.6 | Very sandy sidehill. |
| 92 | 24.8 | 106 | 33.0 | 265 | 3.4 | 2.850 | 1.19 | .502 | 0.4 | Sandy loam. |
| 93 | 25.8 | 107 | 31.3 | 270 | −2.0 | 2.110 | .95 | ........ | 0.4 | Cement gravel. |
| 94 | 25.1 | 113 | 32.8 | 272 | 6.0 | 2.440 | 2.5 | 1.227 | 0.9 | Sandy loam. |
| 95 | 31.3 | 130 | 36.0 | 295 | 13.6 | 2.260 | 6.0 | 2.735 | 2.0 | Porous gravels, evidently seepage. |
| 96 | 68.0 | 159 | 70.5 | 308 | 8.4 | 3.870 | 2.2 | .500 | 0.7 | Clay loam and lava. |
| 97 | 68.0 | 171 | 70.3 | 332 | 24.3 | 4.180 | 5.8 | 1.353 | 1.7 | Clay loam, hardpan. |
| 98 | 32.0 | 122 | 36.5 | 333 | −.76 | 2.620 | .29 | ........ | 0.1 | Impervious clay loam. |
| 99 | Ch'k. | Basin. | ...... | 344 | 34.2 | ........ | ........ | ........ | ........ | Clay loam, hardpan. |
| 100 | 38.3 | 142 | 42.4 | 420 | 12.5 | 5.840 | 2.1 | .826 | 0.5 | Gravel, sand, clay. |
| 101 | Ch'k. | Basin. | ...... | 476 | 28.2 | ........ | ........ | ........ | ........ | Clay loam, hardpan. |
| 102 | 53.5 | 265 | 57.0 | 760 | −4.0 | 2.180 | 1.84 | ........ | 0.2 | Gain, gravel. |
| 103 | 56.7 | 288 | 61.4 | 783 | 10.4 | 2.260 | 4.6 | 1.227 | 0.6 | Compact gravel and clay. |
| 104 | 53.0 | 290 | 58.9 | 788 | −12.7 | 2.140 | 5.9 | ........ | 0.8 | Composite clay and clay irrigated land above canal. |
| 105 | 57.0 | 316 | 62.6 | 832 | 11.1 | 2.060 | 5.4 | 1.408 | 0.6 | Uniform clay loam. |
| 106 | 60.0 | 319 | 64.8 | 877 | 20.9 | 2.940 | 7.1 | 1.701 | 0.8 | Do. |
| 107 | ...... | ........ | ...... | 1,615 | 108 | 3.410 | 31.7 | ........ | 2.0 | Varying clay loam. |
| 108 | ...... | ........ | ...... | 1,755 | 126 | 5.110 | 24.7 | ........ | 1.4 | Bottom on creviced lava rock. |
| 109 | ...... | ........ | ...... | 1,870 | 108 | 8.410 | 12.8 | ........ | 0.7 | Coulee and ditch. |
| 110 | ...... | ........ | ...... | 1,890 | 19.2 | 2.750 | 7.0 | ........ | 0.4 | Gravel, sidehill. |
| 111 | ...... | ........ | ...... | 2,006 | 116 | 8.790 | 13.2 | ........ | 0.7 | Clay loam creviced lava rock. |
| 112 | ...... | ........ | ...... | 2,379 | 13.5 | 4.390 | 3.1 | ........ | 0.1 | ½ concrete lined, ½ clay. |
| 113 | 104.0 | 784 | 110.5 | 2,737 | 93.0 | 5.350 | 17.4 | 2.574 | 0.6 | Deep uniform clay loam. |
| 114 | 107.3 | 829 | 114.3 | 2,798 | 30.4 | 6.070 | 5.0 | .719 | 0.2 | Do. |
| 115 | 107.5 | 831 | 114 | 2,857 | 27.0 | 2.650 | 10.2 | 1.462 | 0.4 | Do. |
| 116 | ...... | ........ | ...... | 2,934 | 54.0 | ........ | ........ | ........ | ........ | Reservoir. |
| 117 | 118.0 | 955 | 123 | 3,097 | 148 | 5.050 | 29.3 | 3.899 | 0.9 | Deep clay loam. |
| 118 | 123.0 | 984 | 129 | 3,192 | 167 | 3.350 | 49.9 | 6.324 | 1.6 | Clay loam, underlain by creviced lava rock. |

Table XXV shows the range of the losses to which the canals were subject in per cent per mile and in cubic feet per square foot of wetted area per 24 hours.

TABLE XXV.—*Range of seepage losses from canals.*

| | Per mile. | Loss per square foot per 24 hours. |
|---|---|---|
| | *Per cent.* | *Cubic feet.* |
| Minimum loss | [1] −5.5 | (1) |
| Maximum loss | 58.3 | 6.32 |
| Average loss (109 sections) | 7.4 | 1.21 |

[1] Gain.

The effect of capacity and other factors upon the losses is shown by the curves in figure 13, which are based upon all of the data secured after eliminating the few sections which showed a gain. These curves

indicate that losses per square foot of wetted area are largely independent of the volume of water flowing in the canal, but that they are slightly influenced by the depth of water over the wetted area, and that the per cent loss per mile is greatly influenced by capacity where

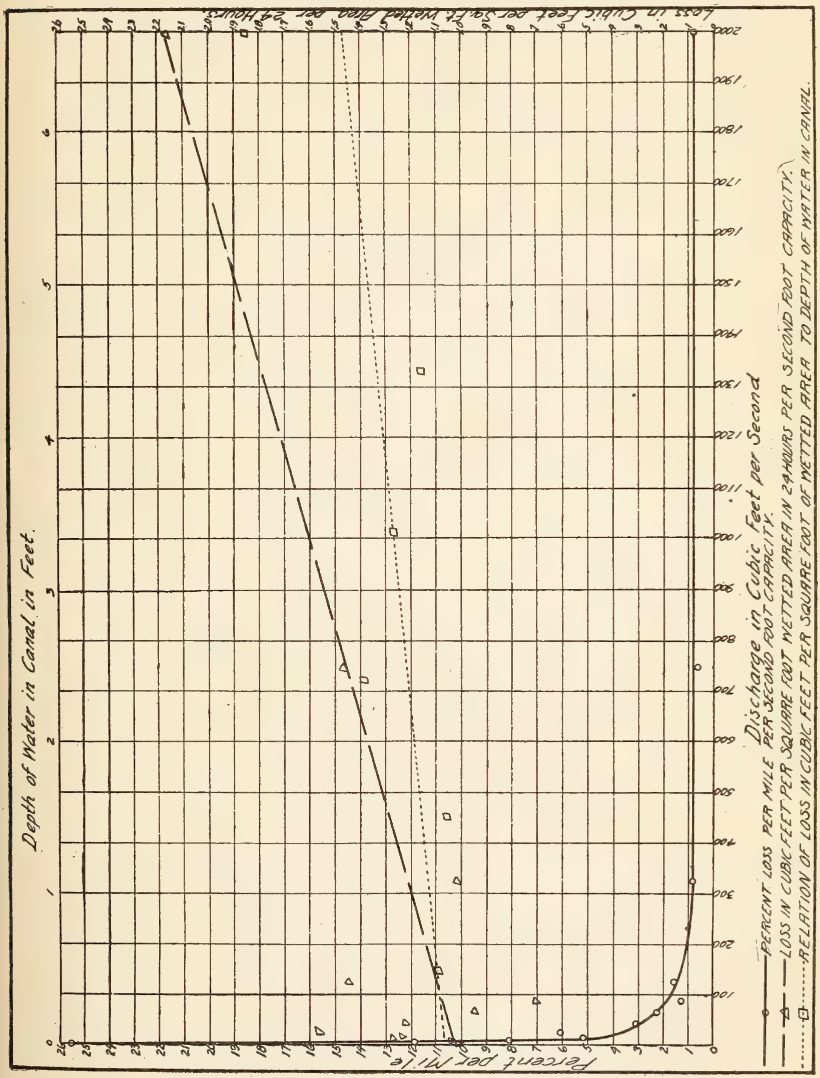



FIG. 13.—Effect of capacity of canal and depth of water on loss in per cent per mile and in cubic feet per square foot of wetted area.

quantities less than 200 second-feet are carried, but that with capacity in excess of 200 second-feet the percentage of loss is remarkably constant. Great care must be used in the designing of small canals to allow for a sufficiently large per cent of loss.

A study of the results shows, among other things:

(1) Small laterals carrying 1 second-foot and less almost invariably lose a large part of the water carried, and the percentage of loss decreases rapidly as the volume carried is increased, thus emphasizing the desirability of rotation systems where the necessity of carrying small amounts is eliminated.

(2) Since certain types of soil have a fairly uniform loss per square foot of canal bed, canals should be designed, other things being equal, with as small a wetted perimeter as possible in comparison to their cross sections.

(3) Porous irrigated land above a canal may cause it to gain instead of lose.

(4) Canals in average southern Idaho soil, which is a medium clay loam, should be designed to withstand a loss of 0.5 to 1.5 cubic feet per square foot of canal bed in 24 hours; 0.5 cubic foot per square foot per day is a safe basis for impervious clay loam soil, about 1 cubic foot per day for medium soil, and 1.5 to 2 cubic feet per square foot per day is a safe basis for somewhat pervious soils.

(5) One per cent per mile is a safe basis for the loss in medium southern Idaho soil with capacities in excess of 200 second-feet.

(6) Canals in gravelly soil should be designed to withstand a loss of 2.5 to 5 cubic feet per square foot of canal bed in 24 hours, depending upon the porosity of the gravel, although it is probable that lining would be profitable if the higher loss were experienced. The procedure must be determined by local economic conditions.

(7) A project having a comparatively long main canal, constructed through earth and unlined, may lose from 20 to as high as 50 per cent of the water diverted before it reaches the farms even in the impervious soils. (See fig. 13.)

## SURVEY OF WASTE LAND IN IDAHO.

It has long been known that not every acre of the gross area contained in a project is irrigated. Engineers, for lack of more accurate data, have commonly assumed that 20 per cent of a typical project is unirrigated because of high spots, corrals, county and private roads, railroad rights of way, etc. Water has been increasing in value to such an extent that there is a great incentive to base projects upon narrower margins each year, and it was evident that the above factor should be carefully determined in order to allow of a design that would not only be economical but would safeguard the future of the newer projects. For the purpose of determining the extent of unirrigated land which exists in a high-class, intensively cultivated project in any one year from all causes, 16,067.8 acres of typical irrigated land, located in two contiguous bodies in the best part of two typical

irrigated districts, were surveyed. Twenty-six sections were surveyed, 20 of them being located under the old canals in the heart of the Boise Valley, in the vicinity of Meridian, and 6 sections in the heart of the South Side Twin Falls project near Kimberly. The entire survey was made with a transit and chain, each crop and each type of waste land being carefully noted. The field notes were plotted on detail paper on a scale of 200 feet to the inch, and the areas were determined with a polar planimeter. The areas surveyed were typical of the better class of Idaho irrigation practice in every respect, and the detailed results secured are shown in the following tables. For convenience the various irrigated areas are grouped in Table XXVI, and the nonirrigated or waste areas in Table XXVII. As numbered in the first column, the 26 sections are identical in the two tables. Nos. 1 to 6, inclusive, in both tables give the data for the six sections near Kimberly, and Nos. 7 to 26, inclusive, for the 20 sections near Meridian.

TABLE XXVI.—*Acres actually irrigated.*

| No. | Hay. | | Grain. | | Pasture. | | Potatoes. | | Orchard. | | Garden. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* |
| 1 | 112.3 | 23.3 | 83.7 | 17.4 | 55.5 | 11.5 | 14.4 | 3.0 | 76.7 | 15.9 | 8.1 | 1.7 |
| 2 | 95.9 | 14.9 | 263.9 | 40.9 | 64.1 | 9.9 | 14.9 | 2.3 | 21.4 | 3.3 | 4.2 | .7 |
| 3 | 228.4 | 35.5 | 67.4 | 10.5 | 71.9 | 11.2 | 12.9 | 2.0 | 25.8 | 4.0 | 11.3 | 1.8 |
| 4 | 86.6 | 15.8 | 112.6 | 20.6 | 9.1 | 1.7 | 19.7 | 3.6 | 204.6 | 37.5 | .3 | .1 |
| 5 | 67.5 | 14.0 | 57.7 | 12.0 | 12.8 | 2.6 | 41.3 | 8.5 | 78.7 | 16.3 | 2.2 | .5 |
| 6 | 52.5 | 10.9 | 96.5 | 20.1 | 34.7 | 7.2 | 15.9 | 3.3 | 66.6 | 13.8 | 1.7 | .3 |
| 7 | 292.6 | 45.4 | 134.0 | 20.8 | 55.5 | 8.6 | 0 | 0 | 111.7 | 17.3 | .4 | .1 |
| 8 | 202.3 | 31.3 | 212.4 | 32.8 | 100.1 | 15.5 | 0 | 0 | 12.6 | 1.9 | 8.5 | 1.3 |
| 9 | 223.5 | 34.6 | 184.0 | 28.5 | 134.5 | 20.8 | 0 | 0 | 56.5 | 8.7 | 0 | 0 |
| 10 | 72.3 | 11.2 | 88.7 | 13.7 | 42.6 | 6.6 | 0 | 8 | 379.0 | 58.6 | 1.1 | .2 |
| 11 | 220.8 | 35.9 | 57.9 | 9.4 | 121.0 | 19.7 | 0 | 0 | 183.1 | 29.8 | 1.0 | .2 |
| 12 | 186.9 | 29.3 | 109.4 | 17.1 | 177.7 | 27.8 | 0 | 0 | 104.7 | 16.4 | 3.0 | .5 |
| 13 | 167.5 | 26.3 | 104.3 | 16.4 | 155.7 | 24.5 | 0 | 0 | 154.0 | 24.2 | 5.6 | .9 |
| 14 | 151.6 | 25.0 | 148.3 | 24.4 | 111.1 | 18.3 | 0 | 0 | 129.3 | 21.3 | 9.9 | 1.6 |
| 15 | 134.6 | 20.5 | 171.7 | 26.1 | 217.2 | 33.1 | 0 | 0 | 67.1 | 10.2 | 10.3 | 1.6 |
| 16 | 139.5 | 21.8 | 200.0 | 31.3 | 113.9 | 17.8 | 18.2 | 2.8 | 105.6 | 16.5 | 7.9 | 1.2 |
| 17 | 215.9 | 33.4 | 308.7 | 47.8 | 10.9 | 1.7 | 0 | 0 | 33.3 | 5.2 | 2.7 | .4 |
| 18 | 219.3 | 34.1 | 253.8 | 39.5 | 18.5 | 2.9 | 0 | 0 | 43.6 | 6.8 | 2.5 | .4 |
| 19 | 319.3 | 49.4 | 205.7 | 31.8 | 82.9 | 12.8 | 0 | 0 | 6.3 | 1.0 | 0 | 0 |
| 20 | 151.3 | 23.8 | 309.1 | 48.6 | 100.1 | 15.7 | 0 | 0 | 17.0 | 2.7 | 5.8 | .9 |
| 21 | 204.3 | 32.0 | 202.8 | 31.8 | 89.0 | 14.0 | 0 | 0 | 45.2 | 7.1 | 3.0 | .5 |
| 22 | 191.3 | 30.2 | 208.1 | 32.9 | 89.7 | 14.2 | 0 | 0 | 109.3 | 17.3 | .6 | .1 |
| 23 | 84.7 | 13.3 | 72.0 | 11.4 | 305.9 | 48.2 | 0 | 0 | 121.6 | 19.2 | 4.4 | .7 |
| 24 | 117.1 | 18.3 | 261.8 | 40.9 | 87.2 | 13.6 | 0 | 0 | 119.7 | 18.7 | 0 | 0 |
| 25 | 197.5 | 31.0 | 233.9 | 36.7 | 120.9 | 18.9 | 0 | 0 | 16.1 | 2.6 | 7.4 | 1.2 |
| 26 | 281.9 | 43.5 | 179.4 | 27.7 | 65.1 | 10.0 | 0 | 0 | 71.2 | 11.0 | 3.7 | .6 |
| Total | 4,417.4 | ...... | 4,327.8 | ...... | 2,447.6 | ...... | 137.3 | ...... | 2,360.7 | ...... | 105.6 | ...... |
| Percentage | ........ | 27.5 | ........ | 26.9 | ........ | 15.2 | ........ | .9 | ........ | 14.7 | ........ | .7 |

TABLE XXVI.—*Acres actually irrigated*—Continued.

| No. | Clover. | | Sagebrush, will be irrigated. | | Corn, beans, and peas. | | Vineyards and berries. | | Miscellaneous. | | Total. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* |
| 1 | 21.3 | 4.4 | 0 | 0 | 9.1 | 1.9 | 0.9 | 0.2 | 58.1 | 12.5 | 440.1 | 91.4 |
| 2 | 0 | 0 | 7.4 | 1.1 | .1 | 0 | .6 | .1 | 89.5 | 13.8 | 562.0 | 87.0 |
| 3 | [1] 0 | 0 | 5.6 | .9 | 0 | 0 | 0 | 0 | 155.8 | 24.2 | 579.1 | 90.0 |
| 4 | 6.5 | 1.9 | 10.1 | 1.9 | 10.5 | 1.8 | 1.3 | .2 | 37.9 | 6.9 | 499.2 | 91.4 |
| 5 | 14.6 | 3.0 | 0 | 0 | 129.7 | 26.8 | 0 | 0 | 34.2 | 7.1 | 438.7 | 90.8 |
| 6 | 52.4 | 10.9 | 11.9 | 2.4 | 80.0 | 1.7 | 0 | ...... | 18.2 | 3.8 | 430.4 | 89.2 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | .7 | .1 | 0 | 0 | 594.9 | 92.3 |
| 8 | 0 | 0 | 58.4 | 9.0 | 0 | 0 | 0 | 0 | 0 | 0 | 594.3 | 91.9 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.7 | .3 | 600.2 | 92.8 |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10.8 | 1.7 | 594.5 | 91.9 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 583.8 | 95.0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4.0 | .6 | 585.7 | 91.6 |
| 13 | 0 | 0 | 3.5 | .6 | 0 | 0 | 0 | 0 | 0 | 0 | 590.6 | 92.8 |
| 14 | 0 | 0 | 0 | 0 | 10.1 | 1.7 | 0 | 0 | 0 | 0 | 560.3 | 92.4 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 2.2 | .3 | 0 | 0 | 603.1 | 91.8 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 585.1 | 91.5 |
| 17 | 0 | 0 | 3.8 | .6 | 0 | 0 | 0 | 0 | 0 | 0 | 575.3 | 89.2 |
| 18 | 0 | 0 | 40.1 | 6.2 | 0 | 0 | 0 | 0 | 0 | 0 | 577.8 | 89.8 |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 614.2 | 95.0 |
| 20 | 0 | 0 | 0 | 0 | 1.6 | .3 | 0 | 0 | 6.2 | 1.0 | 591.1 | 93.0 |
| 21 | 0 | 0 | 58.9 | 9.2 | 0 | 0 | 0 | 0 | 0 | 0 | 603.2 | 94.6 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 599.0 | 94.6 |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 588.6 | 92.7 |
| 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7.2 | 1.1 | 593.0 | 92.5 |
| 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.5 | .3 | 577.3 | 90.6 |
| 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9.0 | 1.4 | 610.3 | 94.1 |
| Total | 94.8 | ...... | 199.7 | ...... | 241.1 | ...... | 5.7 | ...... | 434.1 | ...... | 14,771.8 | ...... |
| Percentage | ........ | .6 | ........ | 1.2 | ........ | ...... | ........ | ...... | ........ | ...... | ........ | 91.9 |

[1] Flax.

TABLE XXVII.—*Waste or nonirrigated acreage.*

| No. | Corrals. | | Barn and stack yards. | | Fence rows. | | Canals and ditches. | | County and private roads. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* |
| 1 | 4.9 | 1.01 | 0 | 0 | 7.7 | 1.6 | 3.4 | 0.7 | 10.4 | 2.2 |
| 2 | 6.5 | 1.0 | 0.7 | 0.1 | 9.0 | 1.4 | 3.9 | .6 | 14.2 | 2.2 |
| 3 | 5.8 | .9 | .1 | 0 | 7.8 | 1.2 | 9.3 | 1.5 | 13.2 | 2.0 |
| 4 | 2.6 | .4 | 1.0 | .2 | 6.5 | 1.2 | 7.5 | 1.4 | 16.4 | 3.0 |
| 5 | 5.7 | 1.2 | 0 | 0 | 12.5 | 2.6 | 2.7 | .6 | 14.1 | 2.9 |
| 6 | 6.6 | 1.4 | 0 | 0 | 9.8 | 2.0 | 6.2 | 1.3 | 14.7 | 3.1 |
| 7 | 6.7 | 1.0 | .9 | .2 | 2.0 | .3 | 10.0 | 1.6 | 12.3 | 1.9 |
| 8 | 5.3 | .8 | .8 | .1 | 1.5 | .2 | 14.2 | 2.2 | 12.3 | 1.9 |
| 9 | 3.4 | .5 | 3.3 | .5 | 1.0 | .2 | 14.4 | 2.2 | 13.0 | 2.0 |
| 10 | 3.0 | .5 | .7 | .1 | 2.8 | .4 | 9.2 | 1.4 | 14.0 | 2.2 |
| 11 | 1.4 | .2 | 2.7 | .4 | 1.2 | .2 | 5.4 | .9 | 13.4 | 2.2 |
| 12 | 8.4 | 1.3 | 2.2 | .3 | 1.9 | .3 | 9.3 | 1.5 | 14.9 | 2.3 |
| 13 | .8 | .1 | 1.5 | .2 | 1.7 | .3 | 5.9 | .9 | 13.3 | 2.1 |
| 14 | 0 | 0 | .3 | 0 | 1.4 | .2 | 4.8 | .8 | 13.5 | 2.2 |
| 15 | 4.2 | .6 | .6 | .1 | 2.0 | .3 | 4.7 | .7 | 14.9 | 2.3 |
| 16 | 4.0 | .6 | 0 | 0 | 1.8 | .3 | 10.8 | 1.9 | 11.7 | 1.8 |
| 17 | 6.7 | 1.0 | 0 | 0 | 1.8 | .3 | 9.5 | 1.5 | 13.3 | 2.1 |
| 18 | 1.6 | .3 | .5 | .1 | 1.5 | .2 | 14.8 | 2.3 | 15.2 | 2.4 |
| 19 | 2.6 | .4 | 1.9 | .3 | 1.2 | .2 | 9.1 | 1.4 | 12.4 | 1.9 |
| 20 | 7.9 | 1.2 | 1.6 | .3 | 2.3 | .4 | 11.4 | 1.8 | 12.3 | 1.9 |
| 21 | .2 | 0 | 3.0 | .5 | 1.0 | .2 | 9.3 | 1.5 | 12.7 | 2.0 |
| 22 | 0 | 0 | .4 | .1 | 1.1 | .2 | 13.0 | 2.1 | 12.1 | 1.9 |
| 23 | .4 | .1 | 0 | 0 | 2.4 | .4 | 13.5 | 2.1 | 15.0 | 2.4 |
| 24 | 1.7 | .3 | .4 | .1 | 1.7 | .3 | 8.1 | 1.3 | 12.5 | 2.0 |
| 25 | 5.2 | .8 | 1.6 | .3 | 1.7 | .3 | 11.9 | 1.9 | 15.5 | 2.4 |
| 26 | 4.4 | .7 | .6 | .1 | 2.6 | .4 | 7.2 | 1.1 | 14.2 | 2.2 |
| Total | 100.0 | ...... | 24.8 | ...... | 87.9 | ...... | 229.5 | ...... | 351.5 | ...... |
| Percentage | ........ | .6 | ........ | .2 | ........ | .6 | ........ | 1.4 | ........ | 2.2 |

TABLE XXVII.—*Waste or nonirrigated acreage*—Continued.

| No. | Railroad right of way. | | Building sites. | | Coulees, sloughs, and creeks. | | Miscellaneous. | | Total. | | Total acreage in section considered. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* | *Acres.* | *P. ct.* | *Acres.* |
| 1 | 5.7 | 1.1 | 0 | 0 | 9.7 | 2.0 | 0.4 | 0.1 | 42.2 | 8.7 | 482.3 |
| 2 | 12.0 | 1.9 | 0 | 0 | 31.8 | 4.9 | 5.4 | .8 | 83.6 | 12.9 | 645.6 |
| 3 | 0 | 0 | 0 | 0 | 25.4 | 3.9 | 2.9 | .5 | 64.5 | 10.0 | 643.6 |
| 4 | .6 | .1 | 0 | 0 | 12.3 | 2.3 | .1 | 0 | 47.0 | 8.6 | 546.2 |
| 5 | 0 | 0 | 0 | 0 | 6.8 | 1.4 | 2.6 | .5 | 44.4 | 9.2 | 483.1 |
| 6 | 5.8 | 1.2 | 0 | 0 | 7.1 | 1.5 | 2.1 | .4 | 52.3 | 10.9 | 482.7 |
| 7 | 0 | 0 | 6.7 | 1.0 | 10.3 | 1.6 | 1.0 | .2 | 49.9 | 7.8 | 644.8 |
| 8 | 0 | 0 | 7.8 | 1.2 | 8.7 | 1.4 | 2.7 | .4 | 53.3 | 8.2 | 647.6 |
| 9 | 0 | 0 | 8.5 | 1.3 | 1.4 | .2 | 1.4 | .2 | 46.4 | 7.2 | 646.6 |
| 10 | 0 | 0 | 8.8 | 1.4 | 14.1 | 2.2 | 0 | 0 | 52.6 | 8.1 | 647.1 |
| 11 | 0 | 0 | 6.3 | 1.0 | .2 | 0 | .2 | 0 | 30.8 | 5.0 | 614.6 |
| 12 | 3.7 | .6 | 7.0 | 1.1 | 6.1 | 1.0 | 0 | 0 | 53.5 | 8.3 | 639.2 |
| 13 | 3.7 | .6 | 12.0 | 1.9 | 7.2 | 1.1 | 0 | 0 | 46.1 | 7.3 | 636.7 |
| 14 | 3.9 | .7 | 7.6 | 1.2 | 15.4 | 2.5 | 0 | 0 | 46.9 | 7.7 | 607.2 |
| 15 | 6.1 | .9 | 9.4 | 1.4 | 12.0 | 1.8 | 0 | 0 | 53.9 | 8.2 | 657.1 |
| 16 | 3.6 | .6 | 7.2 | 1.1 | 12.0 | 1.9 | 3.1 | .1 | 54.2 | 8.5 | 639.3 |
| 17 | 24.1 | 3.7 | 3.2 | .5 | 10.2 | 1.6 | 1.7 | .3 | 70.5 | 10.9 | 645.5 |
| 18 | 24.2 | 3.8 | 4.5 | .7 | 3.0 | 4.7 | 0 | 0 | 65.3 | 10.2 | 643.1 |
| 19 | 0 | 0 | 5.0 | .8 | 0 | 0 | .5 | .1 | 32.7 | 5.1 | 646.9 |
| 20 | 0 | 0 | 7.2 | 1.1 | 1.5 | .2 | .4 | .1 | 44.6 | 7.0 | 635.7 |
| 21 | 0 | 0 | 2.5 | .4 | 0 | 0 | 5.8 | .9 | 34.5 | 5.4 | 637.7 |
| 22 | 0 | 0 | 6.5 | 1.0 | 0 | 0 | 1.1 | .2 | 34.2 | 5.4 | 633.2 |
| 23 | 0 | 0 | 7.1 | 1.1 | 7.7 | 1.2 | 0 | 0 | 46.1 | 7.3 | 634.7 |
| 24 | 0 | 0 | 8.0 | 1.3 | 15.1 | 2.4 | .5 | .1 | 48.0 | 7.5 | 641.0 |
| 25 | 0 | 0 | 7.4 | 1.2 | 14.7 | 2.3 | 2.4 | .4 | 60.4 | 9.5 | 637.7 |
| 26 | 0 | 0 | 6.6 | 1.0 | 2.1 | .3 | .4 | .1 | 38.1 | 5.9 | 648.4 |
| Total | 93.4 | | 139.3 | | 234.8 | | 34.7 | | 1,296.0 | | 16,067.8 |
| Percentage | | .6 | | .9 | | 1.6 | | .2 | | 8.1 | |

A small part of the land surveyed, as indicated by the tables, was yet uncleared and uncultivated and is classed as sagebrush. The survey having been made during two winter seasons, no determination as to the extent of the fallow land could be made. The proportion of this land, however, was practically negligible and could not possibly have exceeded 1 or 2 per cent. The 20 sections included in the investigation in the vicinity of Meridian averaged 10.65 farms per section. Space will not permit of a detailed description of each section included in the investigation or of the results obtained. The results show, in addition to other factors, that the total land unirrigated from all possible causes, even including the unirrigated strips along the fence rows, amounted to only 8.1 per cent of the total area surveyed. The land included was not the best nor the most intensively cultivated of Idaho irrigated land, but it undoubtedly did represent a little better than average conditions, for neither the main canal nor the rough, rolling land that is common along the main stream was included. The data secured therefore seem to demonstrate that well-developed projects will never contain more than 10 to 12½ per cent of land which is waste or unirrigated in any one year from all different causes, provided the percentage is based upon no greater gross area than that from which annual maintenance can be reasonably expected.

## PROPER DUTY OF WATER FOR IDAHO.

The investigations have determined the factors which must be taken into consideration in determining the proper duty for an entire irrigation project. The first factor is the proper duty of water at the land. The results of the investigation indicate that under conditions similar to those obtaining in Idaho on a normal project with medium clay loam should furnish sufficient water so that 2 acre-feet can be retained upon each and every irrigated acre during the season; that this quantity should be delivered under a rotation system in heads of such sizes that economical use can be secured; and that where a project is devoted one half to grain and the other half to alfalfa or other crops requiring a similar volume of water, 18.7 per cent of this 2 acre-feet should be delivered during May, 28.3 per cent during June, 32.8 per cent during July, 17.2 per cent during August, and 2 per cent during the first half of September, there being but little need for irrigation during the month of April and practically none after the middle of September, provided stock water or that used for domestic purposes is not taken into consideration. It has been shown that the farmer must receive approximately 2¼ feet of water per acre at the farm in order for him to retain 2 feet per acre upon the land. Where projects consist in whole or in part of porous soils or of soils with porous subsoils lying closer to the surface than 6 feet, more than 2¼ feet per acre should be delivered to the consumers, the quantity required being largely dependent upon the porosity of the soil.

A conservative estimate of the transmission losses should be made in advance for each project, in either cubic feet per square foot of wetted area or per cent per mile, from the quantity required of canals to furnish sufficient water to all parts of a project. A normal project will be found to lose from 20 to 40 per cent of all water diverted before the water can be delivered to the farmer.

After the duty of water at the land, the size of the project, and the probable transmission losses have been determined, the net area which may be irrigated may be readily found. It then becomes necessary to calculate the extent of waste or nonirrigated land from all causes which will finally be contained in the project. This, added to the net area which can be irrigated, will give the gross area of the project. The extensive survey that was made for the determination of this factor seems to indicate that 90 per cent of a normal project will be irrigated every year after the project is fully developed.

The investigation has demonstrated the adequacy of 2 feet per acre for diversified crops on the better class of soils, but it requires careful husbandry to render this quantity adequate, and it seems evident that but few projects will ever exist, with conditions similar

to those in south Idaho, where an allotment of less than this supply will be justified. It is believed, however, that the volume of water which will produce the maximum yield of crop on any certain variety of soil is in but few cases the proper and economic duty. It is very evident that the cost of the land, of water, the value of the crops produced, and the cost of producing them, as well as the volume of water which will produce the largest yield, must all be taken into consideration when determining the duty for any project. In many places the largest crop has been produced where the most water has been applied, but the yield has been in but few cases proportional to the quantity of water used, and in view of this there is no doubt that, broadly speaking, one would be justified in opening up a project with a higher duty of water where water is very valuable and land comparatively cheap than where land is high and water comparatively inexpensive. The determination of the proper supply of water for an irrigation project is a very serious problem and one that must be given the most careful consideration, for it is fully as serious to err on the side of too little water as it is on the side of too much. If too little water is allotted, the farmers never can produce profitable crops and the lands never will reach their highest possible value, while if too much is allotted the ultimate irrigated area is not only cut down, but the excess supply is almost invariably used, resulting in the rapid water-logging and deterioration of the irrigated lands.

## PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE RELATING TO IRRIGATION.

### AVAILABLE FOR FREE DISTRIBUTION.

How to Build Small Irrigation Ditches. (Farmers' Bulletin 158.)
Practical Information for Beginners in Irrigation. (Farmers' Bulletin 263.)
Use of Windmills in Irrigation in Semiarid West. (Farmers' Bulletin 394.)
Wood Pipe for Conveying Water for Irrigation. (Department Bulletin 155.)
Irrigation in Wyoming. (Office of Experiment Stations Bulletin 205.)

### FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS.

Irrigation in Montana. (Office of Experiment Stations Bulletin 172.) Price, 15 cents.

Irrigation in South Dakota. (Office of Experiment Stations Bulletin 210.) Price, 10 cents.

Irrigation in the State of Washington. (Office of Experiment Stations Bulletin 214.) Price, 10 cents.

Irrigation in Idaho. (Office of Experiment Stations Bulletin 216.) Price, 15 cents.

Delivery of Water to Irrigators. (Office of Experiment Stations Bulletin 229.) Price, 15 cents.

Irrigation in Arizona. (Office of Experiment Stations Bulletin 235.) Price, 20 cents.

Use of Underground Water for Irrigation at Pomona, California. (Office of Experiment Stations Bulletin 236.) Price, 20 cents.

Irrigation in California. (Office of Experiment Stations Bulletin 237.) Price, 10 cents.

Storage of Water for Irrigation Purposes: Earth-fill Dams and Hydraulic-fill Dams. (Office of Experiment Stations Bulletin 249, part 1.) Price, 20 cents.

Storage of Water for Irrigation Purposes: Timber Dams and Rock-fill Dams. (Office of Experiment Stations Bulletin 249, part 2.) Price, 15 cents.

Gate Structures for Irrigation Canals. (Department Bulletin 115.) Price, 20 cents.

Concrete Lining as Applied to Irrigation Canals. (Department Bulletin 126.) Price, 10 cents.



ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY
▽